DEVELOPMENT OF DESIGN TOOLS FOR THE DESIGN OF STEEL BEAMS AS PER INDIAN & INTERNATIONAL STANDARDS

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MAY 2014

DEVELOPMENT OF DESIGN TOOLS FOR THE DESIGN OF STEEL BEAMS AS PER INDIAN & INTERNATIONAL STANDARDS

A thesis

Submitted by

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(110CE0374)

In partial fulfillment of the requirements for the award of

the degree

of

BACHELOR OF TECHNOLOGY

In

CIVIL ENGINEERING

Under the Guidance of

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May 2014

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CERTIFICATE

This is to certify that the thesis entitled, **"DEVELOPMENT OF DESIGN TOOLS FOR THE DESIGN OF STEEL BEAMS AS PER INDIAN & INTERNATIONAL STANDARDS"** submitted by **VAIBHAV RAJ** bearing roll no. **110CE0374** of **Civil Engineering Department,** National Institute of Technology, Rourkela is an authentic record of work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University / Institute for the award of any Degree or Diploma.

Date: 10th May, 2014
Place: Rourkela

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ACKNOWLEDGEMENTS

Foremost I would like to express my earnest gratitude to my advisor **Prof. ROBIN DAVIS P** for his direction, patience and immense knowledge throughout my project. His guidance helped me through my work and composing the thesis. I cannot think of a better advisor to have.

I am thankful to **Prof. RAMAKAR JHA** for our interesting discussions during the presentation of the project.

I would like to extend out my appreciation to all my companions and senior learners, who have constantly encouraged and upheld me in doing my work. I would like to thank all the staff members of Department of Civil Engineering who have always been helpful to me.

I am thankful to various authors of research papers and online resources that has been referred during the course of this project.

A truly unbounded words of thanks to my family for their love and consistent support. Thanks to the Almighty for his blessings.

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ABSTRACT

Steel design codes are in the process of evolution over the years. The design approach has been changing over the years. The Indian codes now follow limit state design approach in line with other inter-national codes. The latest version of the Code of Practice for general construction in steel, IS 800-2007 is based on Limit State Method of design and it supersedes the previous dated version of this code IS 800-1984 which is based on elastic method, [6]. The design based on limit state method involves many equations and parameters. Therefore the design of steel structural members and connections involves tedious equations. In this study, design tools using microsoft excel spreadsheets and charts have been prepared for the design of flexure members which will save the time of engineer’s considerably. Similar tools have also been developed for British Standards BS 5950-2000 and American Standards AISC 360-2010.

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CHAPTER 1
INTRODUCTION

1.1 INTRODUCTION

Iron, in its various forms, has been in usage since several thousand years BC. The two great ancient Indian epics, Ramayana and Mahabharatha, had shown the importance of iron long back and being mostly used as weapons. The Hittites Empire was the first user of iron dated 3 to 4 millenniums ago. There are many evidences of iron usage in our country from the time of Indus Valley civilization. The most important ones are the "Iron pillar, Delhi" and "Howrah Bridge, Kolkata". Recent construction is of the Second Hooghly cable stayed bridge in Kolkata which runs a total length of 823 meters and uses 13200 tonnes of steel, [12].

Steel because of its different favorable circumstances has been credited as a structural configuration material. High quality /weight proportion makes steel an extremely alluring structural material for high rises or tall structures, bridges with long span, structures found on delicate ground, and structures placed in exceptionally seismic regions where strengths following up on the structure because of a tremor are all in all corresponding to the weight of the structure. Appropriately outlined steel structures can have high pliability, which is an essential trademark for opposing stun stacking, for example, impacts or seismic tremors. A ductile structure has vitality-engrossing limit and won't acquire sudden failure. It typically indicates huge noticeable avoidances before failure or breakdown. Steel structures might be raised quickly. This regularly brings about speedier budgetary result. Steel structures could be manufactured with fantastic-workmanship and thin tolerances. It's extremely extraordinary to catch wind of steel development however its exceptionally regular. Steel development of materials has turned into a requirement for the advancement. It has gotten helpful for the business and business divisions for a long time of time.

Figure1. Iron pillar, Delhi, (courtesy: Karunesh Johri)

Figure 2. Howrah Bridge, Kolkata, (hi.wikipedia.org)

1.2 SIGNIFICANCE

Steel design codes are in the process of evolution over the years. The design approach has been changing over the years. The Indian codes now follow limit state design approach in line with other inter-national codes. Different tools are used in the steel and offshore steel industry for the design of steel elements. The need of such design tools is required in situations of primary, secondary and tertiary steel elements in the steel industry. The three kinds of steel elements are the elements that support major, moderate and minor equipment or loading.

1.3 OBJECTIVE

To develop design tools for designing steel beams for prominent code groups:

- Indian Standards
- British Standards
- American codes

1.4 SCOPE

The scope of the study is limited to steel beams.

The design of the beams as per various major codes.

1.5 ORGANISATION OF THE THESIS

Following the brief introduction of the present study, the next four chapters will discuss:

In Chapter 2, coverage of the factors, such as cross-section classification, loading, support conditions, affecting the beam and its behaviour is summed up concisely. Published literature on the various studies conducted on present study are enlisted and considered. Along with this , the procedure for design of steel beams as per prominent code groups has been described in detail.

In Chapter 3, Aptly working of the spreadsheets prepared is also described with an example and a comparison of results been made. Design charts are presented for flexure members and illustrated with an example mentioning the steps adopted.

In Chapter 4, major conclusions showing the importance of present study are explained.

CHAPTER 2
LITERATURE REVIEW

2.1 INTRODUCTION

The literature survey conducted as part of the present study is separated into two sections. The first part summarizes the behaviour of beam with regard to yield capacity. In the second part design provision of steel beam concerning Indian Code, British Standard and American Code are discussed.

2.2 BEAM

Beams are the essential and the most crucial component show in any civil building structure. They are steered horizontally and their essential capacity is to transmit the vertical loads by method for flexural or bending activity. The term 'bending problem' was first investigated by 'Galileo Galilei' in 1638 where he referred it as the study of stresses and deformations in a beam caused due to various forces acting in a direction perpendicular to the beam axis with fibers elongated and compressed along two opposite faces of beam. The twisting power affected into the material of the beam as an aftereffect of the outer loads, self weight, span and outside responses to these loads is known as a bending moment. Twisting and shear extend-the load of a beam. By and large beams are of five sorts, in particular, basically simply supported beam, cantilever beam, fixed beam, continuous beam, and overhanging beam,.

Some important terms to come across in present study are discussed below:

- Dead Load (DL): a load of invariant magnitude and position that acts permanently, including self-weight.
- Imposed Load (LL): load on any structure or member, apart from wind load, caused by the surrounding conditions or use.

- Effective length: it is the length between the centers of supports except where point of application is nonconcentric to the support.
- Shear Force: the inplane force at any transverse cross section of a straight member of a beam.
- Bending Moment: it is the internal reaction due to all the transverse force from either side of the section.
- Lateral Torsional Buckling (LTB): a phenomenon in long span beams where the beam twists and displaces laterally.
- Lateral Restraint: restraint that prevents lateral movement of the compression flange.
- Rotational Capacity: the angle through which a joint can rotate without failing.
- Torsional Restraint: restraint that prevents rotation of a member about its longitudinal axis.

2.2.1 BEHAVIOUR OF STEEL BEAMS

✓ Laterally stable steel beams can fail only by flexure, shear or bearing, accepting that lateral movement of the compression flange is limited, and local buckling is precluded in its entire sort. These three conditions met the criteria for limit state design of steel beams. A Steel beam of sufficient strength can also get unserviceable on the off chance that it can't support its load without excessive deflection and this is considered as a limit state of serviceability.

- ✓ At the point when the beam is enough supported against parallel clasping, the design bending strength is legislated by yielding of the material at the purpose of most extreme moment. The beam is accordingly fit for arriving at its plastic moment limit under the connected burdens. Along these lines the design strength is administered by yield anxiety and the beam is considered laterally supported beam.

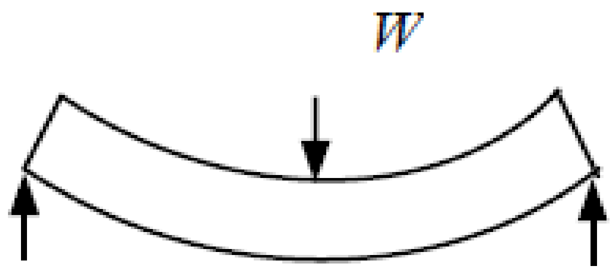


Figure3. Excessive bending causing collapse, Subramanian (2012).

- ✓ Beams have much more excellent quality and solidness while curving about the major axis. Unless they are propped against sidelong diversion and twisting, they are powerless against failure by lateral torsional clasping preceding the achievement of their full inplane plastic moment limit. Such beams are considered laterally unsupported beam.

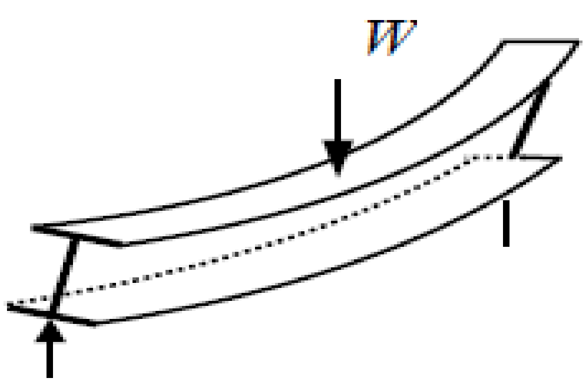


Figure4. Buckling of long beams, Subramanian (2012).

2.2.2 SECTION CLASSIFICATION

Depending upon the parameters (yield strength of the material, web and flange width-to-thickness ratios and type of loading) cross sections are categorized into four classes:

(a) Plastic or Class 1: Those cross sections capable of forming plastic hinges with the rotation capacity for plastic analysis and design.

(b) Compact or Class 2: Those cross sections capable of developing plastic resistance with limited rotation capacity.

(c) Semi-Compact or Class 3: Those cross sections in which width-to-thickness ratio is large and thus local buckling occur prior to the acquirement of yield stress.

(d) Slender or Class 4: Those cross sections in which width-to-thickness ratio is sufficiently large causing the local buckling much before the acquirement of yield stress even in the extreme fibers.

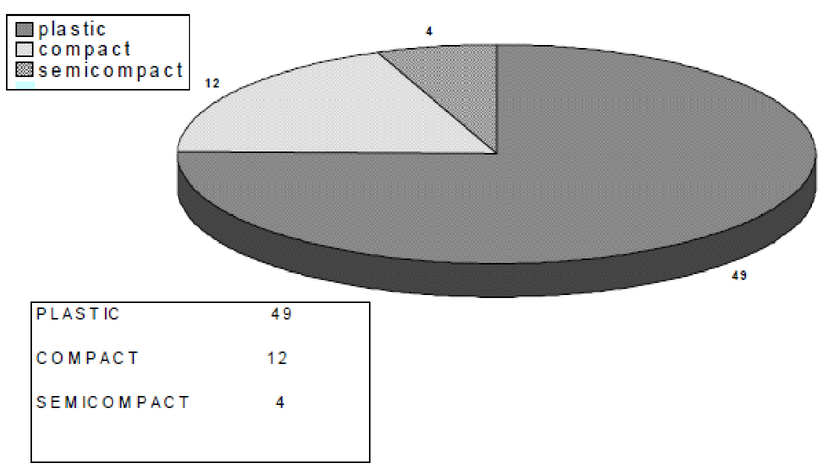


Figure5. Section Classification of Indian Standard Rolled I Sections, [11].

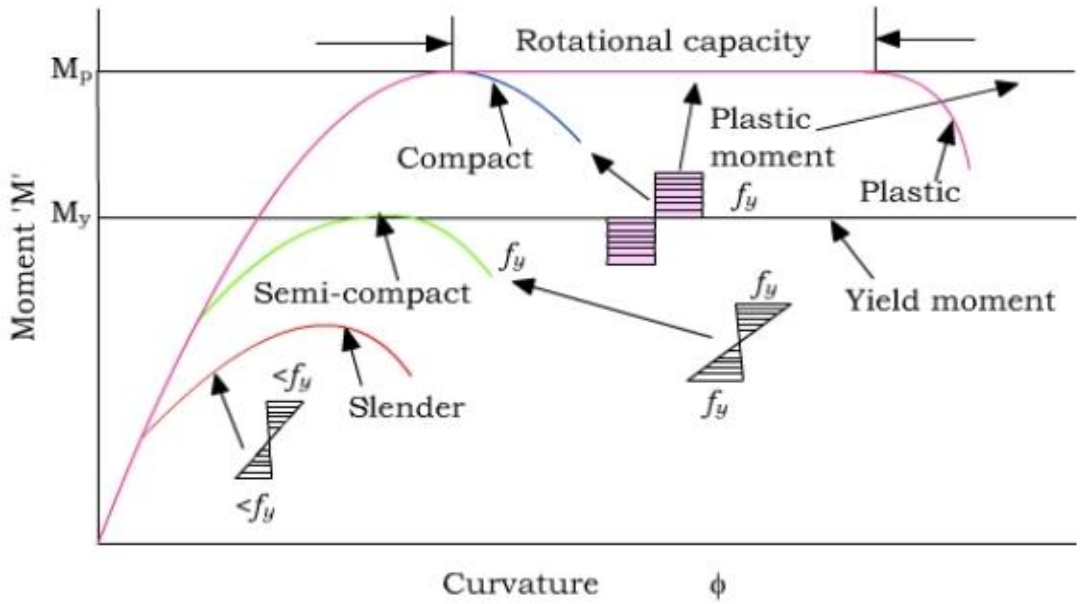


Figure6. Behaviour of 4 cross sections as per IS 800, [9].

2.3 DESIGN CODES

A standard code serves as a reference record. The content spreads outlining points of interest including the design methods and specifications. Most of the nations have developed their own standard codes. In this study, beam is designed as per the procedure documented in the codes, IS Code, AISC Code and BS Code.

2.3.1 INDIAN STANDARDS

Kulkarni and Patil (2011) indicated the utilization of charts as configuration helps for selecting steel sections. Design charts for Indian Standard Channel Section is displayed based on IS 800:2007. Corresponding to each length and for a given section the factored load value is determined using the design equations of the code. Thereafter varying the effective length other factored load values are obtained and a graph is plotted between factored load and effective span length. These charts provides the section directly as the load value the member can withstand can be referred.

IS 800 (2007) is the basic code for general construction in steel structures and is the prime document for any structural design. This standard will result in safe, serviceable and economic construction of steel. It outlines the procedure for design of members subjected to flexure.

Symbols	Definition
A	cross- sectional area
A_v	shear area
b_f	flange width
D	overall depth
E	modulus of elasticity
F_y	characteristics yield stress
F_{yw}	web yield strength
G	modulus of rigidity
M_d	Design bending strength
t_w	web thickness
t_f	flange thickness
V_d	design shear strength

V_n nominal shear strength

Y_{mo} partial safety factor against shear failure

Table1. width to thickness ratio (refer Table2 of IS Code)

Compression Element		Ratio	Class of Section		
			Class 1 Plastic	Class 2 Compact	Class 3 Semi-Compact
Outstanding element of compression flange	Rolled Section	b/t_f	9.4ε	10.5ε	15.7ε
Web of an I section	Neutral axis at mid-depth	d/t_w	84ε	105ε	126ε

Where $\varepsilon = \sqrt{(250/f_y)}$

<u>Design for Shear</u> (refer Clause8.4 of IS Code)

Generally shear capacity of section is more than adequate to resist shear, except for short heavily loaded beams or with heavy loads close to the supports.

V in a beam due to outside actions shall satisfy

$V \leq V_d$

Where

$V_d = V_n/Y_{mo}$

$Y_{mo} = 1.1$ (refer Table 5 of IS Code)

$V_n = V_p = A_v * f_{yw} / \sqrt{3}$

$A_v = h * t_w$

Design for Bending

When a beam undergoes bending there is a deformation in shape and internal stresses are developed.

✓ Design bending strength of laterally Supported Beams

The design moment of beams, adequately supported against buckling (laterally supported beams) is administered by yielding stress. The factored design moment, M at any section, in a beam due to external actions shall satisfy $M \leq M_d$

Based on Shear force V values the design bending strength M_d of a beam may be computed as follows (refer Cause 8.2.1 of IS 800:2007):

When shear force $V < 0.6\ V_d$ (refer Clause 8.2.1.2 of IS 800:2007) where V_d is design shear strength of the cross-section.

$M_d = (\beta_b Z_p f_y) / Y_{mo} <= 1.2\ Z_e\ f_y / Y_{mo}$ for simply supported beams

$<= 1.5\ Z_e\ f_y / Y_{mo}$ for cantilever supported beams

When shear force $V > 0.6\ V_d$ (refer Clause 8.2.1.3 of IS Code)

The design bending strength M_d shall be

$M_d = M_{dv}$

M_{dv} = design bending strength under high shear (refer Clause 9.2.2 of IS Code)

$= M_d - \beta (M_d - M_{fd}) <= 1.2\ Z_e\ f_y / Y_{mo}$ for Plastic or Compact section

$= Z_e\ f_y / Y_{mo}$ for Semi-Compact section where

$\beta = (2V/ V_d \quad - \quad 1)^2$

$M_{fd} = Z_{fd}\, f_y / Y_{mo}$

✓ Design bending strength of laterally Unsupported Beams(refer Clause 8.2.2 of IS Code)

The design bending strength of laterally unsupported beam as controlled by lateral torsional buckling:

$M_d = \beta_b Z_p f_{bd}$

Where

$\beta_b = 1.0$ for plastic and compact sections.

$= Z_e / Z_p$ for semi-compact sections.

$f_{bd} = X_{LT}\, f_y / Y_{mo}$

$X_{LT} = 1 / [\text{Ø}_{LT} + (\text{Ø}_{LT}{}^2 - \lambda_{LT}{}^2)^{0.5}] \quad \leq 1.0$

$\text{Ø}_{LT} = 0.5[1 + \alpha_{LT}(\lambda_{LT} - 0.2) + \lambda_{LT}{}^2]$

For rolled steel section $\alpha_{LT} = 0.21$

$\lambda_{LT} = \sqrt{(\beta_b Z_p f_y / M_{cr})} \leq \sqrt{(1.2\, Z_e\, f_y / M_{cr})}$

$= \sqrt{(f_y / f_{cr,b})}$

$$f_{cr,b} = \frac{1.1 * \pi^2 * E}{(L_{LT} / r_y)^2} * [1 + \frac{1 * (L_{LT} / r_y)^2}{20 * (h_f / t_f)^2}]^{0.5}$$

Table2. Effective length under different restraints (refer Table15 of IS Code)

Sl No.	Conditions of Restraint at Supports		Loading Conditions	
	Torsional Restraint	Warping Restraint	Normal	Destabilizing
1	Fully restrained	Both flanges fully restrained	0.70L	0.85L
2	Fully restrained	Compression flange fully restrained	0.75L	0.90L
3	Fully restrained	Both flanges fully restrained	0.80L	0.95L
4	Fully restrained	Compression flange partially restrained	0.85L	1.00L
5	Fully restrained	Warping not restrained in both flanges	1.00 L	1.20L
6	Partially restrained by bottom flange support connection	Warping not restrained in both flanges	1.0L + 2D	1.2L + 2D
7	Partially restrained by bottom flange bearing support	Warping not restrained in both flanges	1.2L + 2D	1.4L + 2D

Design for Deflection

Although a beam may be sufficient to resist bending stress, it may sag or create problems such as cracking of finished ceiling or ponding of roof.

The maximum allowable deflection due to live load only is L/300.(refer Table 6 of the code)

2.3.2 British Standards

BS 5950 (2000) is a limit state code. There are nine parts out of which part 1 deals with the code of practice for design of steel beams using hot rolled sections.

Symbols	Definition
A	Area
A_v	shear area of a member
B	width
b	outstand
D	depth of section
d	depth of web
E	modulus of elasticity of steel
F_v	shear force in a member
I_x, I_y	second moment of area about the major and minor axes respectively
L	length or span
L_E	effective length
M	Actual moment
M_b	buckling resistance moment
m	equivalent uniform moment factor

P_v shear capacity of a member

p_b Bending strength (lateral torsional buckling)

p_y design strength

r_x, r_y radius of gyration about the major and minor axes respectively

S_x, S_y plastic modulus about the major and minor axes respectively

T thickness of flange

t thickness of web

u buckling parameter of a cross secction

v slenderness factor for a beam

x torsional index of a cross section

Z_x, Z_y section modulus about the major and minor axes respectively

λ slenderness

λ_{LO} limiting equivalent slenderness(lateral torsional buckling)

λ_{LT} equivalent slenderness(lateral torsional buckling)

Grade of Steel:

3 grades of steel are generally used, namely S275, S355 and S460.

Grade S460 is the strongest and grade S275 is of lowest strength. In this S stands for 'Structural' and the number indicates the yield strength of the material in N/mm^2.

Design strength varies with the grade of steel and also with the thickness.

Table3. Determination of Design strength, p_y

Steel grade	Thickness less than or equal to (mm)	Design strength, p_y (N/mm^2)
S275	16	275
	40	265
	63	255
	80	245
	100	235
	150	225
S355	16	355
	40	345
	63	335
	80	325
	100	315
	150	295
S460	16	460
	40	440
	63	430
	80	410
	100	400

Table4. Classification of Section

Type of element (all Rolled Sections)	Class of section		
	(1) Plastic	(2) Compact	(3) Semi-Compacct
Outstand element of compression flange	$b/T \leq 9\varepsilon$	$b/T \leq 10\varepsilon$	$b/T \leq 15\varepsilon$
Web with neutral axis at mid-depth	$d/t \leq 80\varepsilon$	$d/t \leq 100\varepsilon$	$d/t \leq 120\varepsilon$

Where

$$\varepsilon = \sqrt{(275/ p_y)}$$

Design for shear strength (refer Clause 4.2.3 of BS 5950:2000)

The shear acting on the member shall satisfy the condition:

$F_v \leq P_v$, where

$P_v = 0.6 * p_y * A_v$

$A_v = tD$

Design for Moment

When $F_v < 0.6 * P_v$, it is low shear load condition. Hence moment is calculated as per Clause 4.2.5.2 of the BS Code.

For class1 and class2,

$M_c = p_y * S \quad \leq 1.2\, p_y * Z$ for simply supported beams

$\leq 1.2\, p_y * Z$ for cantilever supported beams

For class3,

$M_c = p_y * Z$

When Pv > Fv > 0.6*Pv , it is high shear load condition. Hence moment is calculated as per clause 4.2.5.3 of the BS Code.

For class1 and class2,

$M_c = p_y * (S - \rho S_v)$

For class3,

$M_c = p_y *(Z - \rho S_v/1.5)$

Where

$\rho = (2F_v/P_v - 1)^2$

$S_v = t*D^2/4$

<u>Design for Lateral Torsional Buckling</u>

$M_b = p_b*S_x$ Class1 and Class2

$= p_b*Z_x$ Class3

Where

$p_b = (p_E*p_y) / [\text{Ø}_{LT} + (\text{Ø}_{LT} – p_E*p_y)^{0.5}]$

$p_E = (\pi^2E/ \lambda_{LT}^2)$

$\text{Ø}_{LT} = [p_y + (\eta_{LT} + 1)p_E] / 2$

$\eta_{LT} = \alpha_{LT}(\lambda_{LT} - \lambda_{LO})/1000$

$\alpha_{LT} = 7.0$

$\lambda_{LT} = u*v*\lambda*\sqrt{\beta_w}$

where

$\lambda = L_E/r_y$

$v = ƛ/x$

$\beta_w = 1$ Class1 and Class2

$= Z_x/S_x$ Class3

Design for Deflection

The maximum deflection allowed in a section due to live load only is L/360. (refer Table8 of the code).

2.3.3 AMERICAN STANDARDS

Elhouar (2012) put forward that design charts and tables are more efficient in carrying out the tasks as compared to advanced programs. He produces unbraced design beam charts as an MS Excel spreadsheet application similar to the AISC Manual of Steel Construction. He insists on using these tools to their fullest as we find that with a minimum number of inputs beam design chart is obtained. These charts are an extremely helpful complex set of curves that were handled to encourage the structural designer's occupation of selecting a satisfactory cross area for an unbraced beam segment of length L_b and subjected to a bending moment M_u.

AISC 360 (2010) provides a treatment for design of steel beams in accordance to Load and Factor Design provisions. The code provides a detailed overview of the design equations both for ultimate state conditon and serviceability criteria.

Symbols	Definition
A_w	web area
C_b	lateral torsional buckling modification factor
C_w	warping consttant
E	modulus of elasticity
F_{cr}	critical stress
F_n	nominal stress
F_y	specified minimum yield stress

G	shear moudulus of elasticity
I_x, I_y	moment of inertia about major and minor axes respectively.
J	torsional constant
L_b	distance between braces
L_p	limiting laterally unbraced length for the limit state of yielding
L_r	limiting laterally unbraced length for the limit state of inelastic LTB
M_n	nominal flexural strength
M_p	plastic bending moment
M_r	limiting buckling moment
M_u	factored load moment
M_y	moment representing the onset of yielding at the extreme firbres
M_{cr}	critical buckling moment
M_c	available flexural strength
V_c	available shear strength
V_u	factored shear
V_n	nominal shear strength
λ	width-to-thickness ratio

λ_p upper limit for compact sections

λ_r upper limit for non-compact sections

Section Classification

For I shaped rolled sections.

$\lambda \leq \lambda_p$ Compact

$\lambda_p < \lambda \leq \lambda_r$ Non-Compact

$\lambda > \lambda_r$ Slender

Table5. width-to-thickness ratio

Element	λ	λ_p	λ_r
Flange	$b_f/2t_f$	$0.38*\sqrt{E/F_y}$	$1.0*\sqrt{E/F_y}$
web	h/t_w	$3.76*\sqrt{E/F_y}$	$5.7*\sqrt{E/F_y}$

Design for Flexure

Nominal flexural strength M_n is the lowest value of (a) yielding, (b) lateral torsional buckling, (c) flange local buckling, and (d) web local buckling

(a) Yielding

Flexural strength = $Ø_b*M_n$ ($Ø_b$=0.9)

$M_n = M_p = F_y*Z_x$ $\leq 1.5M_y$

Where $M_y = F_y*S_x$

(b) Lateral torsional buckling

Flexural strength= $Ø_b*M_n$ ($Øb=0.9$)

$M_n = C_b[M_p – (M_p-M_r)(L_b-L_p)/(L_r-L_p)] \quad \leq M_p \quad$ (for $L_p < L_b \leq L_r$)

$= M_{cr} \quad < M_p \quad$ (for $L_b > L_r$)

Where

$C_b = 1.0$

$M_r = 0.7*F_y*S_x$

$L_p = 1.76*r_y*\sqrt{E/F_y}$

$L_r = 1.95*r_{ts}*(E/0.7F_y)*\sqrt{(Jc/S_x*h_o) + \sqrt{(Jc/S_x*h_o)^2 + 6.76*(0.7F_y/E)^2}}$

(c) Flange local buckling

If $\lambda \leq \lambda_p$ no FLB

If $\lambda_p < \lambda \leq \lambda_r$ the flange is non-compact, and

$M_n= [M_p – (M_p-M_r)(\lambda - \lambda_p)/(\lambda_r - \lambda_p)] \quad \leq M_p$

(d) Web local buckling

If $\lambda \leq \lambda_p$ no WLB

If $\lambda_p < \lambda \leq \lambda_r$ the web is non-compact, and

$M_n= [M_p – (M_p-M_r)(\lambda - \lambda_p)/(\lambda_r - \lambda_p)] \qquad \leq M_p$

Design for Shear

For $h/t_w \leq 260$:

$V_u = Ø_v*V_n \qquad (Ø_v = 0.9)$

$V_n = 0.6*F_y*A_w \qquad h/t_w \leq 2.45*\sqrt{E/F_y}$

$= [0.6*F_y*A_w*2.45*\sqrt{E/F_y}] / h/t_w \qquad 2.45*\sqrt{E/F_y} < h/t_w \leq 3.07*\sqrt{E/F_y}$

$= [A_w *4.52*E] / (h/t_w)^2 \qquad 3.07*\sqrt{E/F_y} < h/t_w \leq 260$

Design for Deflection

Despite the fact that strength is the major criteria for selecting a section, sometimes even an adequate section may become unusable if it fails in deflection. Deflections due to both dead and live loads are considered important in this code. The maximum deflection caused due to dead load + live load and live load are L/240 and L/360 respectively.

2.4 SUMMARY

Overview of beam behaviour is discussed in first part of this chapter. The second part includes the detailed methodology adopted for the design of steel beams. The equations outlined here as per various standards are used in the next chapter for development of design tools.

CHAPTER 3

DEVELOPMENT OF DESIGN TOOL

3.1 INTRODUCTION

The first section of this chapter incorporates the point by point approach received for the outline of steel beams as per different guidelines from the previous chapter and utilizing it for making of design tools using spreadsheets. The results have also been verified from staad checks and comparison is made. The second part involves the use of charts for the design of flexure members and demonstrated with an example.

3.2 SPREADSHEET FOR DESIGN OF BEAMS AS PER IS 800:2007

The design sheet created facilitates the work of selecting an appropriate section for steel beam. To use this spreadsheet, the steps are:

Step1: If the user has to go for Indian Standards for beam design, choose the 'INDIAN CODE' option. A macro named 'Indian' come into operation. In the drop down box a set of Standard rolled I sections will be displayed. Select any section.

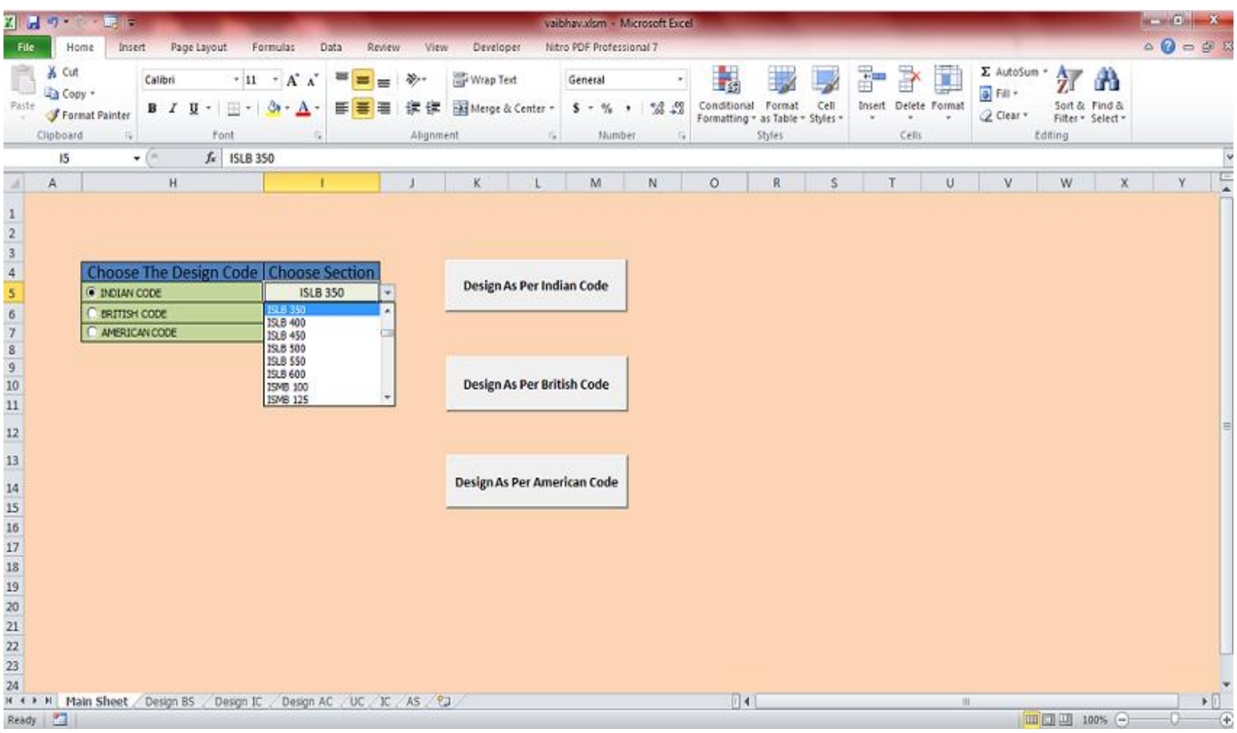
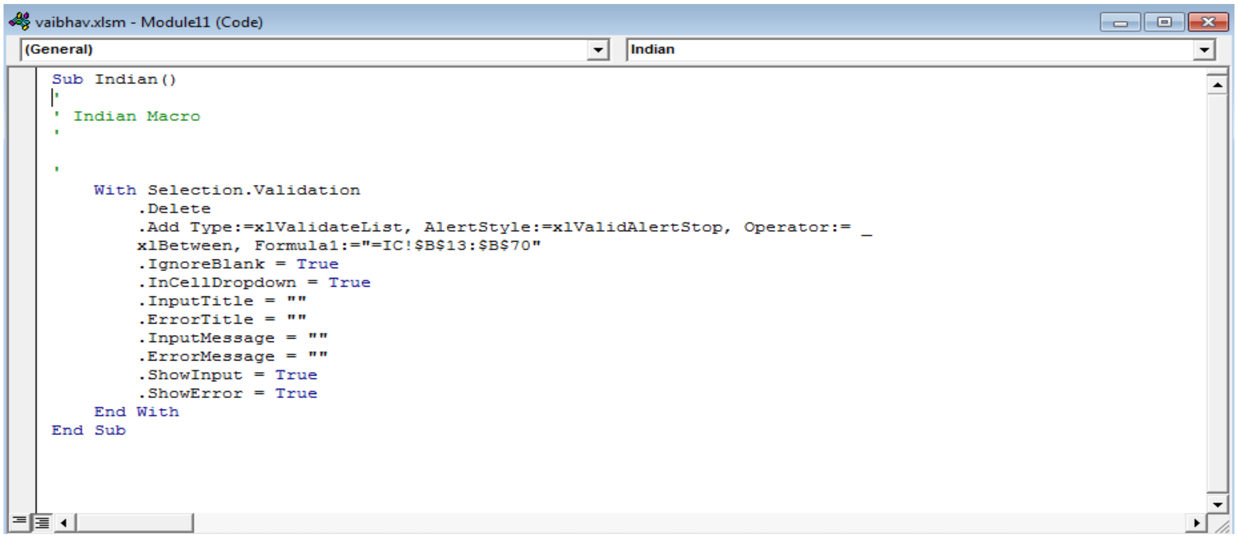


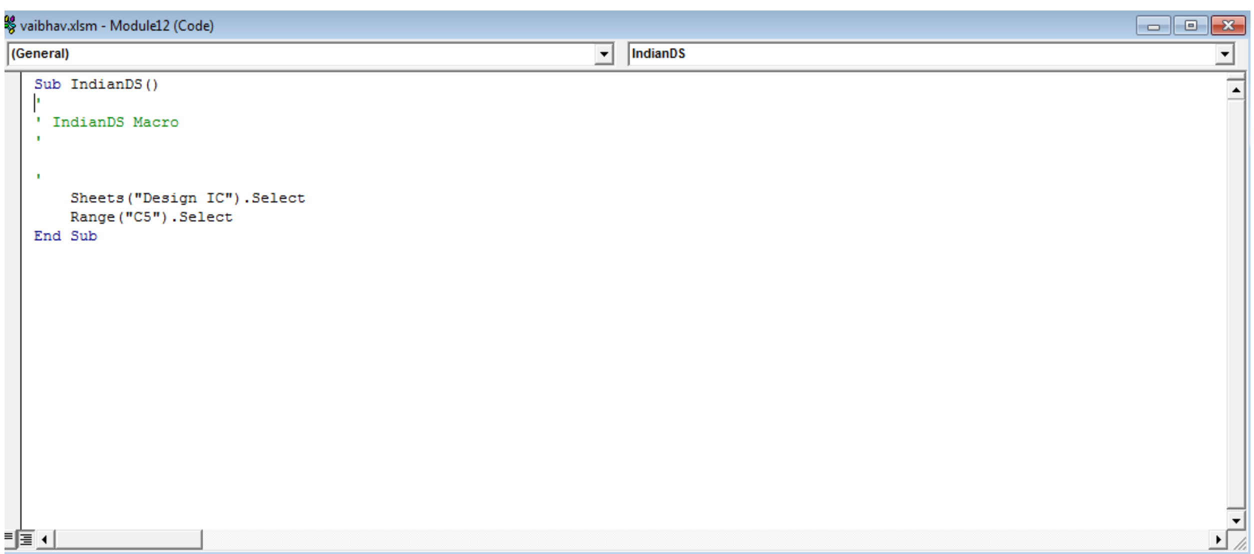
Figure7. Selection of Indian Code and Indian Rolled Steel Selection from the Main Sheet




```
Sub Indian()
'
' Indian Macro
'

'
    With Selection.Validation
        .Delete
        .Add Type:=xlValidateList, AlertStyle:=xlValidAlertStop, Operator:= _
        xlBetween, Formula1:="=IC!$B$13:$B$70"
        .IgnoreBlank = True
        .InCellDropdown = True
        .InputTitle = ""
        .ErrorTitle = ""
        .InputMessage = ""
        .ErrorMessage = ""
        .ShowInput = True
        .ShowError = True
    End With
End Sub
```

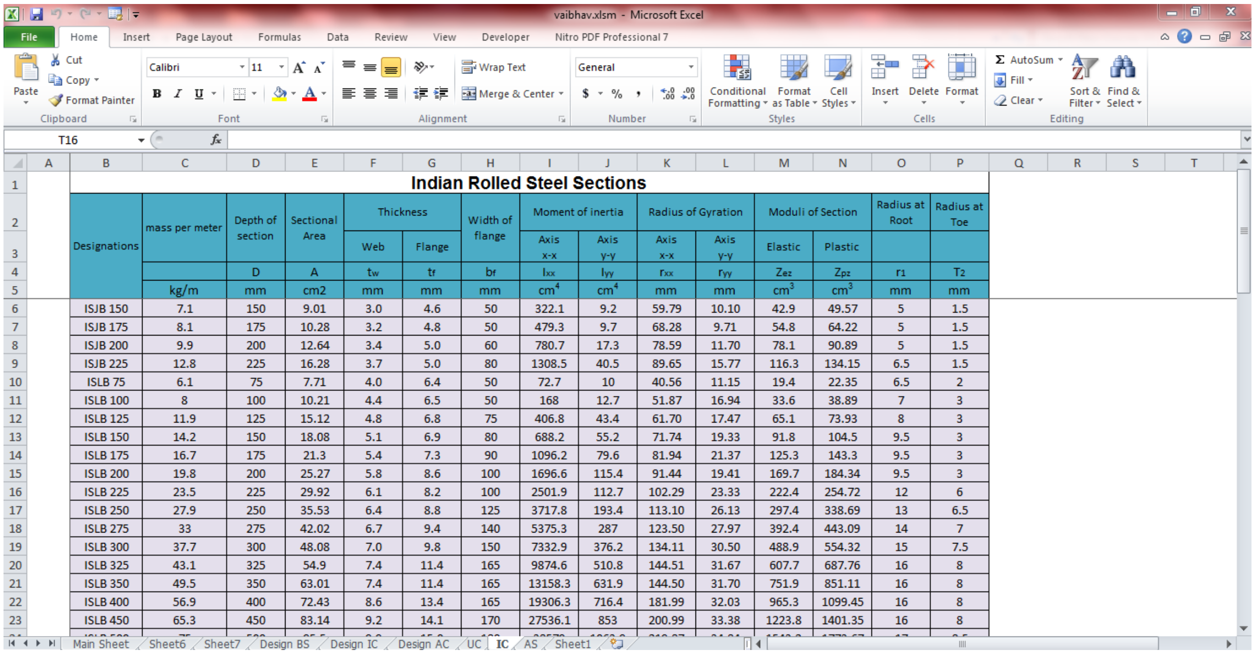
Figure8. Visual Basic code for Indian macro

Step2: Click on the command ‘Design As Per Indian Code’. Now the macro ‘IndianDS’ runs and user is taken to a new sheet ‘Design IC’. In this sheet the section is matched from sheet ‘IC’ and properties are displayed.




```
Sub IndianDS()
'
' IndianDS Macro
'

'
    Sheets("Design IC").Select
    Range("C5").Select
End Sub
```

Figure9. Visual Basic code for IndianDS macro



Indian Rolled Steel Sections

Designations	mass per meter	Depth of section	Sectional Area	Thickness Web	Thickness Flange	Width of flange	Moment of inertia Axis x-x	Moment of inertia Axis y-y	Radius of Gyration Axis x-x	Radius of Gyration Axis y-y	Moduli of Section Elastic	Moduli of Section Plastic	Radius at Root	Radius at Toe
		D	A	t_w	t_f	b_f	I_{xx}	I_{yy}	r_{xx}	r_{yy}	Z_{ez}	Z_{pz}	r_1	T_2
	kg/m	mm	cm2	mm	mm	mm	cm^4	cm^4	mm	mm	cm^3	cm^3	mm	mm
ISJB 150	7.1	150	9.01	3.0	4.6	50	322.1	9.2	59.79	10.10	42.9	49.57	5	1.5
ISJB 175	8.1	175	10.28	3.2	4.8	50	479.3	9.7	68.28	9.71	54.8	64.22	5	1.5
ISJB 200	9.9	200	12.64	3.4	5.0	60	780.7	17.3	78.59	11.70	78.1	90.89	5	1.5
ISJB 225	12.8	225	16.28	3.7	5.0	80	1308.5	40.5	89.65	15.77	116.3	134.15	6.5	1.5
ISLB 75	6.1	75	7.71	4.0	6.4	50	72.7	10	40.56	11.15	19.4	22.35	6.5	2
ISLB 100	8	100	10.21	4.4	6.5	50	168	12.7	51.87	16.94	33.6	38.89	7	3
ISLB 125	11.9	125	15.12	4.8	6.8	75	406.8	43.4	61.70	17.47	65.1	73.93	8	3
ISLB 150	14.2	150	18.08	5.1	6.9	80	688.2	55.2	71.74	19.33	91.8	104.5	9.5	3
ISLB 175	16.7	175	21.3	5.4	7.3	90	1096.2	79.6	81.94	21.37	125.3	143.3	9.5	3
ISLB 200	19.8	200	25.27	5.8	8.6	100	1696.6	115.4	91.44	19.41	169.7	184.34	9.5	3
ISLB 225	23.5	225	29.92	6.1	8.2	100	2501.9	112.7	102.29	23.33	222.4	254.72	12	6
ISLB 250	27.9	250	35.53	6.4	8.8	125	3717.8	193.4	113.10	26.13	297.4	338.69	13	6.5
ISLB 275	33	275	42.02	6.7	9.4	140	5375.3	287	123.50	27.97	392.4	443.09	14	7
ISLB 300	37.7	300	48.08	7.0	9.8	150	7332.9	376.2	134.11	30.50	488.9	554.32	15	7.5
ISLB 325	43.1	325	54.9	7.4	11.4	165	9874.6	510.8	144.51	31.67	607.7	687.76	16	8
ISLB 350	49.5	350	63.01	7.4	11.4	165	13158.3	631.9	144.50	31.70	751.9	851.11	16	8
ISLB 400	56.9	400	72.43	8.6	13.4	165	19306.3	716.4	181.99	32.03	965.3	1099.45	16	8
ISLB 450	65.3	450	83.14	9.2	14.1	170	27536.1	853	200.99	33.38	1223.8	1401.35	16	8

Figure10. Properties of Indian Rolled Steel Sections

Step3: The user is required to fill the parameters along with the support condition.

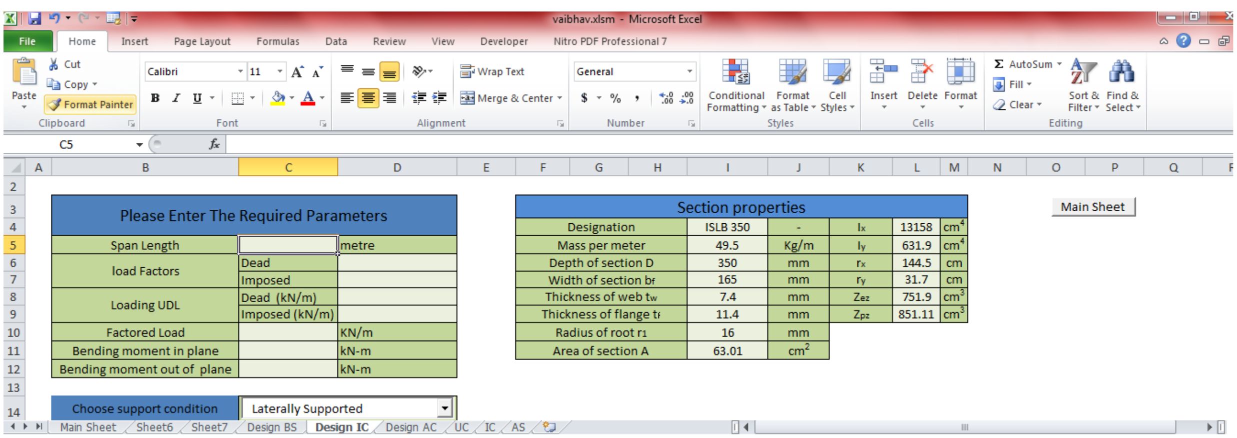


Figure11. Input parameters to be filled by the user

Step4: After finishing the above work, a detailed result is displayed indicating the status of the section. If the section is unsafe revise the section.

Steel Beam Design As Per Indian Code IS800:2007

Please Enter The Required Parameters		
Span Length	5	metre
load Factors	Dead	1.5
	Imposed	1.5
Loading UDL	Dead (kN/m)	20
	Imposed (kN/m)	20
Factored Load	60.00	KN/m
Bending moment in plane	187.50	kN-m
Bending moment out of plane	0	kN-m

Section properties					
Designation	ISLB 350	-	I_x	13158	cm^4
Mass per meter	49.5	Kg/m	I_y	631.9	cm^4
Depth of section D	350	mm	r_x	144.5	cm
Width of section b_f	165	mm	r_y	31.7	cm
Thickness of web t_w	7.4	mm	Z_{ez}	751.9	cm^3
Thickness of flange t_f	11.4	mm	Z_{pz}	851.11	cm^3
Radius of root r_1	16	mm			
Area of section A	63.01	cm^2			

Choose support condition	Laterally Supported

Section Classification		
Web	Plastic	Table 2
flange	Plastic	Table 2
Class of section	Plastic	Table 2

Detailed Results: SHEAR CAPACITY		
Actual shear V (kN)	150.00	
Allowable shear V_d(kN)	339.85	As per Cl. 8.4
Usage Factor	0.44	SAFE
LOW SHEAR LOAD CONDITION i.e.. 0.6*Vd >V		
Detailed Results: MOMENT		
Actual Moment M(Kn-m)	189.02	
Allowable Moment M_d (kN-m)	193.20	As per Cl 8.2.1.2
Usage Factor	0.98	SAFE

Detailed Results: DEFLECTION		
Actual Deflection LL (m)	0.006	
Allowable Deflection LL (m)	0.017	Table 6
Usage Factor	0.37	SAFE

Detailed Results: LATERAL TORSIONAL MOMENT		
Actual moment	-	kN-m
Effective Length		
L (m)	Factor	L_{LT} (m)
Comp. bending stress corresponding to elastic lateral buckling F_{cb} (N/mm^2)		
weaker axis	-	
Non dimensional slenderness ratio λ_{LT}		
weaker axis	-	
$\varnothing_{LT}$	-	
Design bending compressive stress f_{bd} (N/mm		
	-	
Design bending moment M_d (kNm)		
	-	
Usage Factor	-	-

Figure12. Excelsheet showing the adequacy of the beam

The chosen section is safe for use . Now we can check for the compatibility of the section with laterally unsupported condition and using the same input parameters.

Steel Beam Design As Per Indian Code IS800:2007

Please Enter The Required Parameters		
Span Length	5	metre
load Factors	Dead	1.5
	Imposed	1.5
Loading UDL	Dead (kN/m)	20
	Imposed (kN/m)	20
Factored Load	60.00	KN/m
Bending moment in plane	187.50	kN-m
Bending moment out of plane	0	kN-m

Section properties					
Designation	ISLB 350	-	I_x	13158	cm^4
Mass per meter	49.5	Kg/m	I_y	631.9	cm^4
Depth of section D	350	mm	r_x	144.5	cm
Width of section b_f	165	mm	r_y	31.7	cm
Thickness of web t_w	7.4	mm	Z_{ez}	751.9	cm^3
Thickness of flange t_f	11.4	mm	Z_{pz}	851.11	cm^3
Radius of root r_1	16	mm			
Area of section A	63.01	cm^2			

Choose support condition	Laterally Unsupported

Section Classification		
Web	Plastic	Table 2
flange	Plastic	Table 2
Class of section	Plastic	Table 2

Detailed Results: SHEAR CAPACITY		
Actual shear V (kN)	150.00	
Allowable shear V_d(kN)	339.85	As per Cl. 8.4
Usage Factor	0.44	SAFE
LOW SHEAR LOAD CONDITION i.e.. 0.6*Vd >V		
Detailed Results: MOMENT		
Actual Moment M(Kn-m)	-	
Allowable Moment M_d (kN-m)	-	-
Usage Factor	-	-

Detailed Results: DEFLECTION		
Actual Deflection LL (m)	0.006	
Allowable Deflection LL (m)	0.017	Table 6
Usage Factor	0.37	SAFE

Detailed Results: LATERAL TORSIONAL MOMENT		
Actual moment	189.02	kN-m
Effective Length		
L (m)	Factor	L_{LT} (m)
5	1	5
Comp. bending stress corresponding to elastic lateral buckling F_{cb} (N/mm^2)		
weaker axis	135.50	
Non dimensional slenderness ratio λ_{LT}		
weaker axis	1.36	
$\varnothing_{LT}$	1.54	
Design bending compressive stress f_{bd} (N/mm		
	99.75	
Design bending moment M_d (kNm)		
	84.89	
Usage Factor	2.23	NOT SAFE

Figure13. Excelsheet showing the adequacy of the beam under LTB

The member fails now due to lateral torsional buckling. Hence we must go for the higher section.

3.2.1 VERIFICATION OF DESIGN TOOL

Beam Details

Beam span length = 5m

Simply supported beam

Load Details

Dead load=20kN/m

Live load=20kN/m

Design of Beam

Step1: calculation of factored load

W=60kN/m

Step2:calculation of maximum Bending Moment and Shear Force

M= (W*L^2)/8 = 187.5kN/m

V= (W*L)/2 = 150kN

Step3:choosing a trial section

Select ISLB350

Properties:

D=350mm

b_f=165mm

t_f=11.4mm

$d=D-2(t_f+r_1)$=295.2mm

t_w=7.4mm

I_{xx}=13200 X $10^6$$mm^4$

Z_e=751.9 X $10^3$$mm^3$

Z_p=851.11 X $10^3$$mm^3$

<u>Classification of Section:</u>

The section is classified as plastic.

<u>Step4: Design shear strength</u>

V_d=(f_y * h * t_w)/(√3 * Y_{mo})= 340kN > 150kN

0.6V_d=204kN > 150kN

<u>Step5: Design capacity of section</u>

d/t_w=39.9 < 67ε

M_d= β_b * Z_p * f_y/Y_{mo}=193.43 kNm <1.2Z_e*f_y/Y_{mo} (=205kNm)

Also M_d > M

<u>Step6: Deflection limit(LL only)</u>

δ= 5wl^4/384EI = 6.165mm

maximum deflection allowed=L/300= 16.67 mm

The chosen section is adequate.

3.3 EXCEL SHEET FOR DESIGN OF BEAMS AS PER BS 5950:2000

The design sheet made encourages the work of selecting a fitting section for steel beam. To use this spreadsheet, the steps are:

Step1: If the user has to go for British Standards for beam design, choose the 'BRITISH CODE' option. A macro named 'British' come into operation. In the drop down box a set of British Universal sections will be displayed. Select any section.

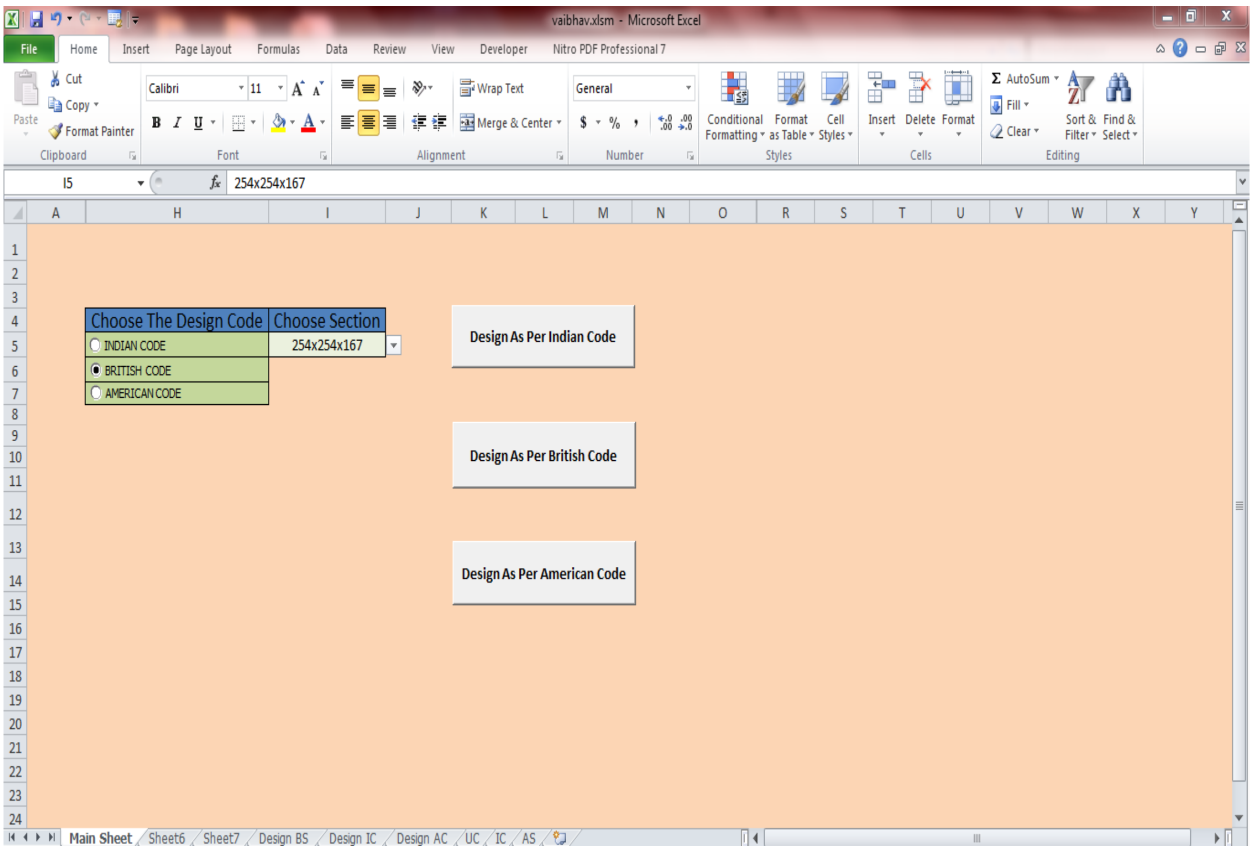
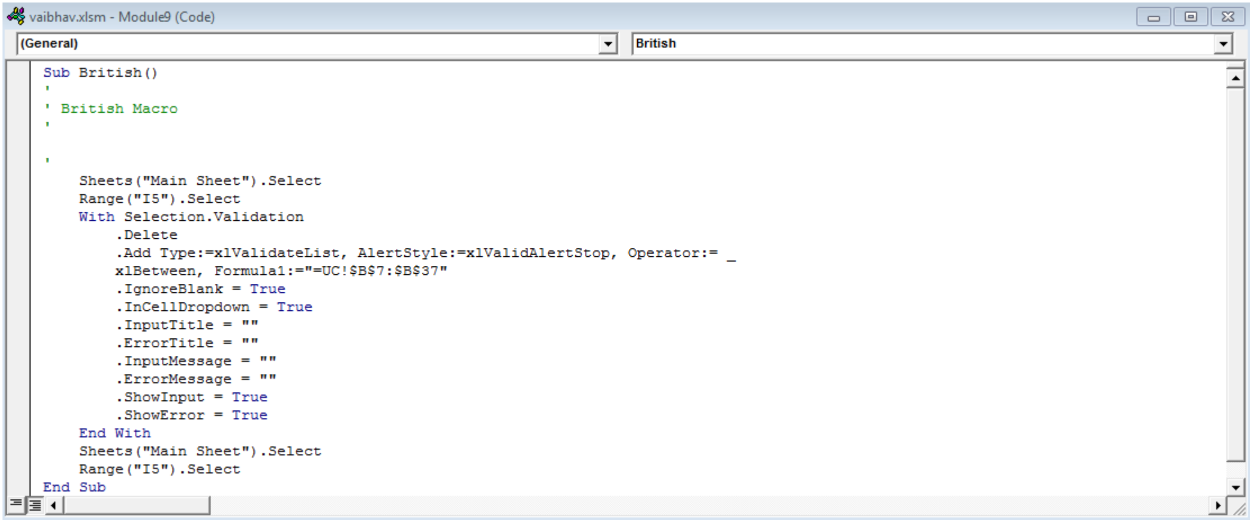


Figure14. Selection of British Code and Britsh Steel Selection from the Main Sheet



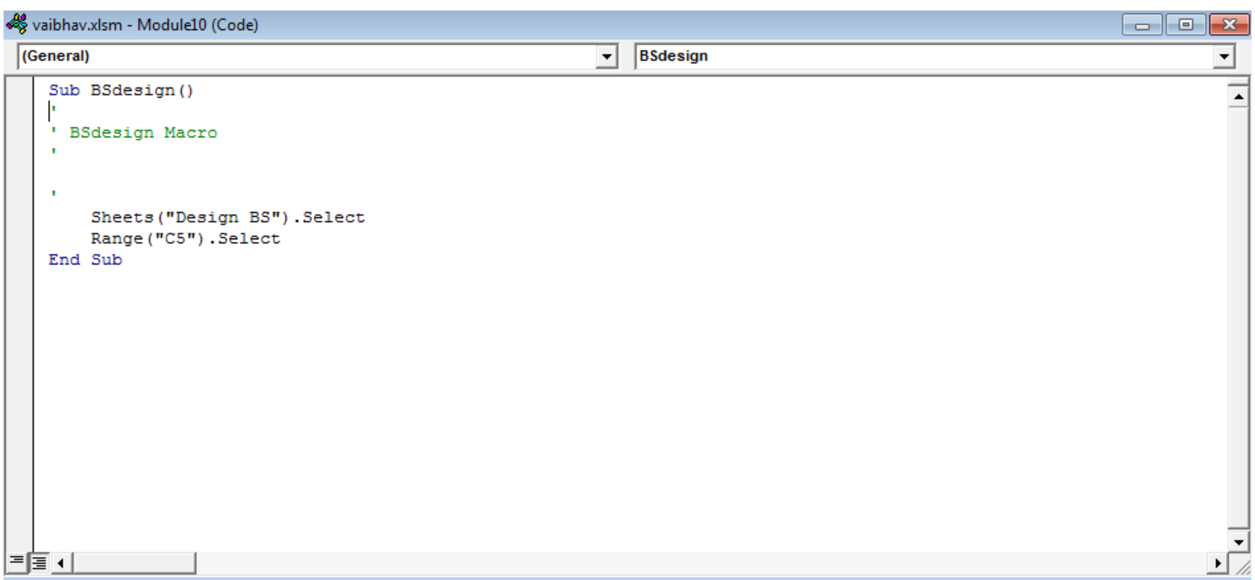
vaibhav.xlsm - Module9 (Code)

(General) | British

```
Sub British()
'
' British Macro
'

'
    Sheets("Main Sheet").Select
    Range("I5").Select
    With Selection.Validation
        .Delete
        .Add Type:=xlValidateList, AlertStyle:=xlValidAlertStop, Operator:= _
        xlBetween, Formula1:="=UC!$B$7:$B$37"
        .IgnoreBlank = True
        .InCellDropdown = True
        .InputTitle = ""
        .ErrorTitle = ""
        .InputMessage = ""
        .ErrorMessage = ""
        .ShowInput = True
        .ShowError = True
    End With
    Sheets("Main Sheet").Select
    Range("I5").Select
End Sub
```

Figure15. Visual Basic code for British macro

<u>Step2</u>: Click on the command ‘Design As Per British Code’. Now the macro ‘BSdesign’ runs and user is taken to a new sheet ‘Design BS’. In this sheet the section is matched from sheet ‘UC’ and properties are displayed.

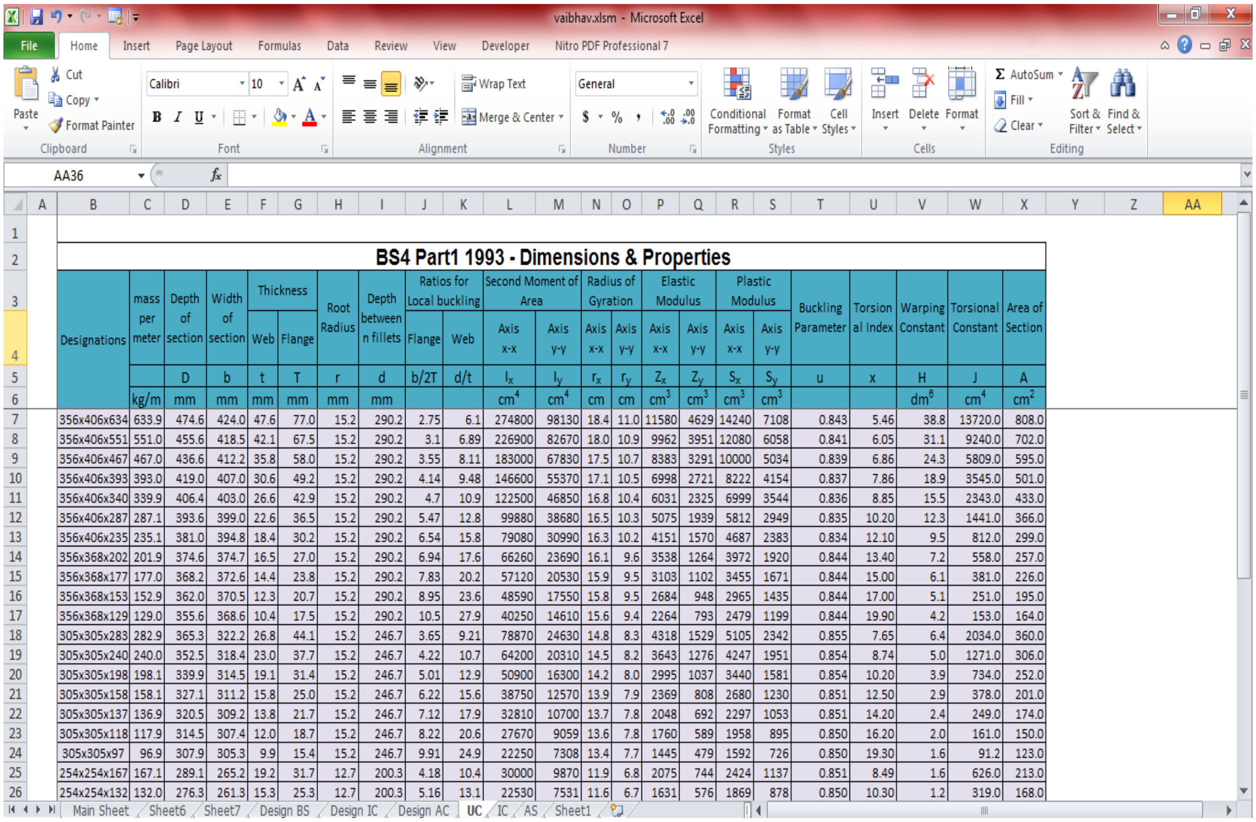


vaibhav.xlsm - Module10 (Code)

(General) | BSdesign

```
Sub BSdesign()
'
' BSdesign Macro
'

'
    Sheets("Design BS").Select
    Range("C5").Select
End Sub
```

Figure16. Visual Basic code for BSdesign macro

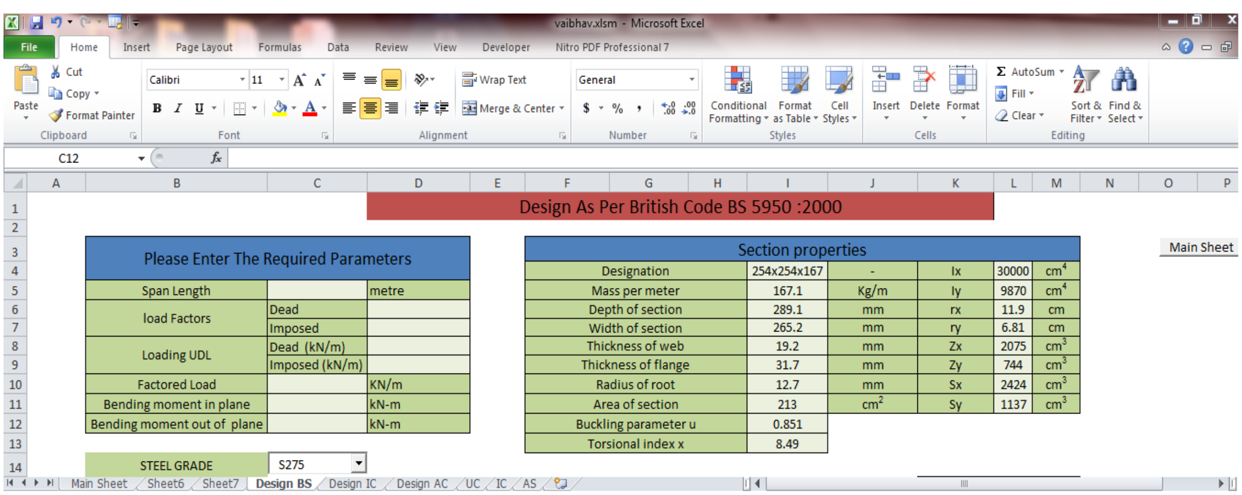


BS4 Part1 1993 - Dimensions & Properties

Designations	mass per meter	Depth of section D	Width of section b	Thickness Web t	Thickness Flange T	Root Radius r	Depth between fillets d	Ratios for Local buckling Flange b/2T	Ratios for Local buckling Web d/t	Second Moment of Area Axis x-x I_x	Second Moment of Area Axis y-y I_y	Radius of Gyration Axis x-x r_x	Radius of Gyration Axis y-y r_y	Elastic Modulus Axis x-x Z_x	Elastic Modulus Axis y-y Z_y	Plastic Modulus Axis x-x S_x	Plastic Modulus Axis y-y S_y	Buckling Parameter u	Torsional Index x	Warping Constant H	Torsional Constant J	Area of Section A
	kg/m	mm	mm	mm	mm	mm	mm			cm^4	cm^4	cm	cm	cm^3	cm^3	cm^3	cm^3			dm^6	cm^4	cm^2
356x406x634	633.9	474.6	424.0	47.6	77.0	15.2	290.2	2.75	6.1	274800	98130	18.4	11.0	11580	4629	14240	7108	0.843	5.46	38.8	13720.0	808.0
356x406x551	551.0	455.6	418.5	42.1	67.5	15.2	290.2	3.1	6.89	226900	82670	18.0	10.9	9962	3951	12080	6058	0.841	6.05	31.1	9240.0	702.0
356x406x467	467.0	436.6	412.2	35.8	58.0	15.2	290.2	3.55	8.11	183000	67830	17.5	10.7	8383	3291	10000	5034	0.839	6.86	24.3	5809.0	595.0
356x406x393	393.0	419.0	407.0	30.6	49.2	15.2	290.2	4.14	9.48	146600	55370	17.1	10.5	6998	2721	8222	4154	0.837	7.86	18.9	3545.0	501.0
356x406x340	339.9	406.4	403.0	26.6	42.9	15.2	290.2	4.7	10.9	122500	46850	16.8	10.4	6031	2325	6999	3544	0.836	8.85	15.5	2343.0	433.0
356x406x287	287.1	393.6	399.0	22.6	36.5	15.2	290.2	5.47	12.8	99880	38680	16.5	10.3	5075	1939	5812	2949	0.835	10.20	12.3	1441.0	366.0
356x406x235	235.1	381.0	394.8	18.4	30.2	15.2	290.2	6.54	15.8	79080	30990	16.3	10.2	4151	1570	4687	2383	0.834	12.10	9.5	812.0	299.0
356x368x202	201.9	374.6	374.7	16.5	27.0	15.2	290.2	6.94	17.6	66260	23690	16.1	9.6	3538	1264	3972	1920	0.844	13.40	7.2	558.0	257.0
356x368x177	177.0	368.2	372.6	14.4	23.8	15.2	290.2	7.83	20.2	57120	20530	15.9	9.5	3103	1102	3455	1671	0.844	15.00	6.1	381.0	226.0
356x368x153	152.9	362.0	370.5	12.3	20.7	15.2	290.2	8.95	23.6	48590	17550	15.8	9.5	2684	948	2965	1435	0.844	17.00	5.1	251.0	195.0
356x368x129	129.0	355.6	368.6	10.4	17.5	15.2	290.2	10.5	27.9	40250	14610	15.6	9.4	2264	793	2479	1199	0.844	19.90	4.2	153.0	164.0
305x305x283	282.9	365.3	322.2	26.8	44.1	15.2	246.7	3.65	9.21	78870	24630	14.8	8.3	4318	1529	5105	2342	0.855	7.65	6.4	2034.0	360.0
305x305x240	240.0	352.5	318.4	23.0	37.7	15.2	246.7	4.22	10.7	64200	20310	14.5	8.2	3643	1276	4247	1951	0.854	8.74	5.0	1271.0	306.0
305x305x198	198.1	339.9	314.5	19.1	31.4	15.2	246.7	5.01	12.9	50900	16300	14.2	8.0	2995	1037	3440	1581	0.854	10.20	3.9	734.0	252.0
305x305x158	158.1	327.1	311.2	15.8	25.0	15.2	246.7	6.22	15.6	38750	12570	13.9	7.9	2369	808	2680	1230	0.851	12.50	2.9	378.0	201.0
305x305x137	136.9	320.5	309.2	13.8	21.7	15.2	246.7	7.12	17.9	32810	10700	13.7	7.8	2048	692	2297	1053	0.851	14.20	2.4	249.0	174.0
305x305x118	117.9	314.5	307.4	12.0	18.7	15.2	246.7	8.22	20.6	27670	9059	13.6	7.8	1760	589	1958	895	0.850	16.20	2.0	161.0	150.0
305x305x97	96.9	307.9	305.3	9.9	15.4	15.2	246.7	9.91	24.9	22250	7308	13.4	7.7	1445	479	1592	726	0.850	19.30	1.6	91.2	123.0
254x254x167	167.1	289.1	265.2	19.2	31.7	12.7	200.3	4.18	10.4	30000	9870	11.9	6.8	2075	744	2424	1137	0.851	8.49	1.6	626.0	213.0
254x254x132	132.0	276.3	261.3	15.3	25.3	12.7	200.3	5.16	13.1	22530	7531	11.6	6.7	1631	576	1869	878	0.850	10.30	1.2	319.0	168.0

Figure17. Properties of British Steel Sections

Step3: The user is required to fill the parameters along with the support condition.



Design As Per British Code BS 5950 :2000

Please Enter The Required Parameters		
Span Length		metre
load Factors	Dead	
	Imposed	
Loading UDL	Dead (kN/m)	
	Imposed (kN/m)	
Factored Load		KN/m
Bending moment in plane		kN-m
Bending moment out of plane		kN-m
STEEL GRADE	S275	

Section properties					
Designation	254x254x167	-	Ix	30000	cm^4
Mass per meter	167.1	Kg/m	Iy	9870	cm^4
Depth of section	289.1	mm	rx	11.9	cm
Width of section	265.2	mm	ry	6.81	cm
Thickness of web	19.2	mm	Zx	2075	cm^3
Thickness of flange	31.7	mm	Zy	744	cm^3
Radius of root	12.7	mm	Sx	2424	cm^3
Area of section	213	cm^2	Sy	1137	cm^3
Buckling parameter u	0.851				
Torsional index x	8.49				

Figure18. Input parameters to be filled by the user

<u>Step4</u>: After finishing the above work, a detailed result is displayed indicating the status of the section. If the section is unsafe revise the section.

Design As Per British Code BS 5950 :2000

Please Enter The Required Parameters		
Span Length	5	metre
load Factors	Dead	1.4
	Imposed	1.6
Loading UDL	Dead (kN/m)	21.43
	Imposed (kN/m)	18.75
Factored Load	60.0	KN/m
Bending moment in plane	187.5	kN-m
Bending moment out of plane	0	kN-m

STEEL GRADE	S275	
Design Strength p_y	265	N/mm^2
ε	1.02	

Section properties					
Designation	254x254x167	-	Ix	30000	cm^4
Mass per meter	167.1	Kg/m	Iy	9870	cm^4
Depth of section	289.1	mm	rx	11.9	cm
Width of section	265.2	mm	ry	6.81	cm
Thickness of web	19.2	mm	Zx	2075	cm^3
Thickness of flange	31.7	mm	Zy	744	cm^3
Radius of root	12.7	mm	Sx	2424	cm^3
Area of section	213	cm^2	Sy	1137	cm^3
Buckling parameter u	0.851				
Torsional index x	8.49				

E	205000	N/mm^2

summary of results		
CLAUSE	RATIO	STATUS
BS 4.2.3	0.170	PASS
BS 4.3.6	0.308	PASS
BS 4.8.3.2	0.300	PASS
BS 4.8.3.3.1	0.350	PASS
BS 4.8.3.3.2	0.308	PASS

Section Classification		
Web	Plastic	Table 11
flange	Plastic	Table 11
Class of section	Plastic	Table 11

LOW SHEAR LOAD CONDITION i.e.. 0.6*Pv >Fv

Detailed Results: SHEAR CAPACITY		
Actual Shear F_v (kN)	150.01	
section shear capacity P_v (kN)	882.56	As per Cl. 4.2.3
Usage Factor	0.17	SAFE

Detailed Results: MOMENT		
Actual moment (kN-m)	192.63	
section moment capacity (kN-m)	642.36	As per Cl. 4.2.5
Usage Factor	0.30	SAFE

Detailed Results: DEFLECTION		
Actual Deflection LL (m)	0.008	
Allowable Deflection LL (m)	0.01	Table 8
Usage Factor	0.57	SAFE

LATERAL TORSIONAL BUCKLING MOMENT

limiting slenderness	34.95	
effective length		
L	Factor	L_E
m		m
5	0.85	4.25
radius of gyration	0.0681	m
Slenderness ratio	62.408	
slenderness factor	0.721	
β_w	1	
equivalent slenderness	38.289	
Robertson constant	7	
perry factor	0.023	
P_E	1380.102	N/mm^2
ϕ_{LT}	838.672	

bending strength p_b	257.601	N/mm^2
buckling resistance moment M_b	624.425	kN-m
uniforn moment factor m_{lt}	1	
Usage Factor	0.31	SAFE

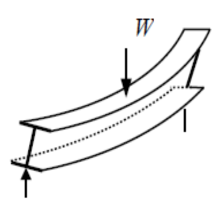


Figure19. Excelsheet showing the adequacy of the beam

3.3.1 VERIFICATION OF DESIGN TOOL WITH STAAD OUTPUT

```
ALL UNITS ARE - KN   METE (UNLESS OTHERWISE NOTED)

MEMBER      TABLE        RESULT/   CRITICAL COND/     RATIO/      LOADING/
                           FX            MY             MZ        LOCATION
=======================================================================

     1 ST UC254X254X167 PASS     BS-4.3.6           0.311          1
                         0.00           0.00        187.50        0.00
=======================================================================

MATERIAL DATA
   Grade of steel            =  S 275
   Modulus of elasticity     =  205 kN/mm2
   Design Strength  (py)     =  265  N/mm2

DESIGN DATA (units - kN,m)    BS5950-1/2000
   Section Class             :   PLASTIC

                                   z-z  axis       y-y  axis
   Moment Capacity           :        642.4          295.9
   Reduced Moment Capacity   :        642.4          295.9
   Shear Capacity            :       2406.0          882.6

BUCKLING CALCULATIONS (units - kN,m)
(axis nomenclature as per design code)

   LTB Moment Capacity (kNm) and LTB Length (m):   602.23,    5.000
   LTB Coefficients & Associated Moments (kNm):
   mLT =    1.00  :   mx =   0.00   :  my =   0.00   :  myx =   0.00
   Mlt =  187.50  :   Mx =    0.00  :  My =   0.00   :   My =   0.00
```

Figure20. Staad result for beam design using British Standards

3.3.2 COMPARISON OF RESULTS

CRITICAL LOADS FOR EACH CLAUSE CHECK (units- kN,m):

CLAUSE	RATIO	LOAD	FX	VY	VZ	MZ	MY
BS-4.2.3-(Y)	0.170	1	-	150.0	-	-	-
BS-4.3.6	0.311	1	-	150.0	-	187.5	-
BS-4.8.3.2	0.085	1	0.0	0.0	0.0	187.5	0.0
BS-4.8.3.3.1	0.341	1	0.0	-	-	187.5	0.0
BS-4.8.3.3.2	0.311	1	0.0	-	-	187.5	0.0

(a) Staad check

summary of results

CLAUSE	RATIO	STATUS
BS 4.2.3	0.170	PASS
BS 4.3.6	0.308	PASS
BS 4.8.3.2	0.300	PASS
BS 4.8.3.3.1	0.350	PASS
BS 4.8.3.3.2	0.308	PASS

(b) Excel check

Figure21. Comparison of checks performed in British Standards

Checks performed in spreadsheets as per British Standard clauses are fairly same as those executed by staad. The stress ratio value as per clause BS 4.2.3 are 0.170 in both cases.

3.4 SPREADSHEET FOR DESIGN OF BEAMS AS PER AISC 360:2010

The design sheet made encourages the work of selecting a fitting section for steel beam. To use this spreadsheet, the steps are:

Step1: If the user has to go for American Standards for beam design, choose the 'AMERICAN CODE' option. A macro named 'american' come into operation. In the drop down box a set of American wide flange W sections will be displayed. Select any section.

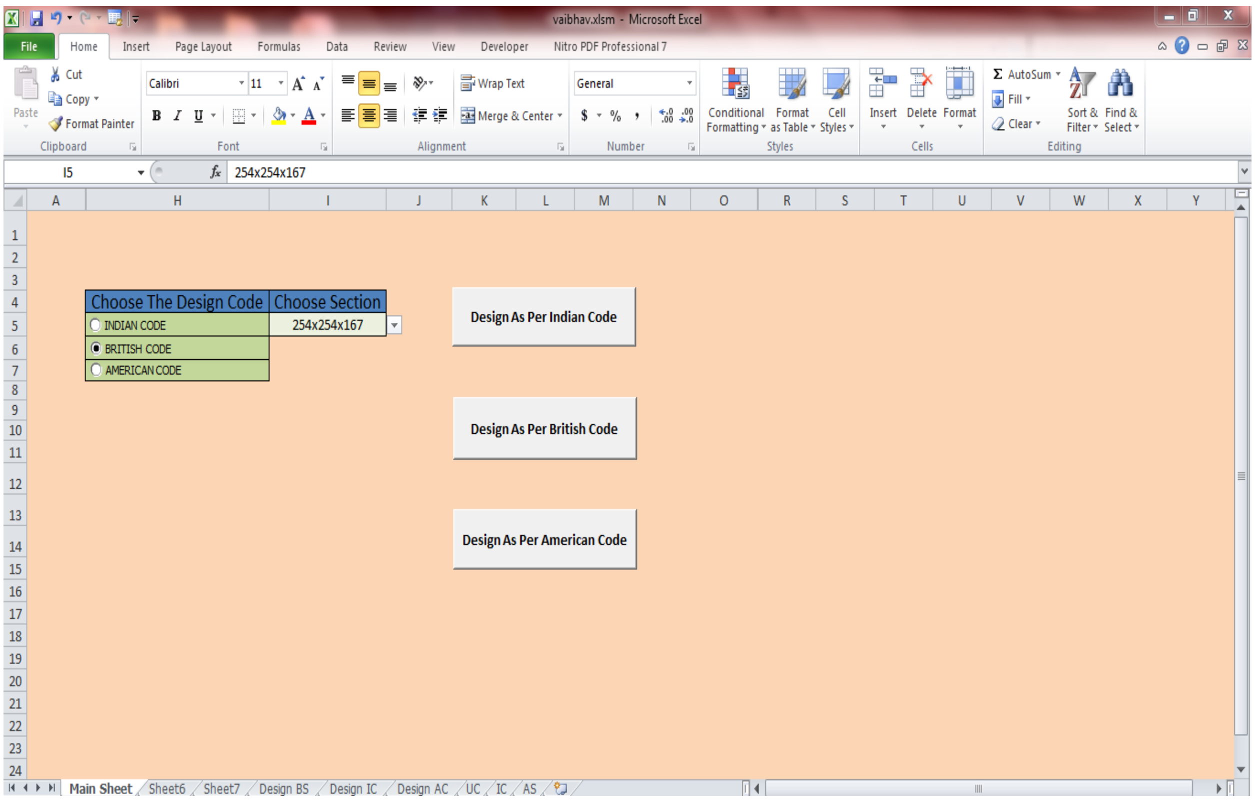
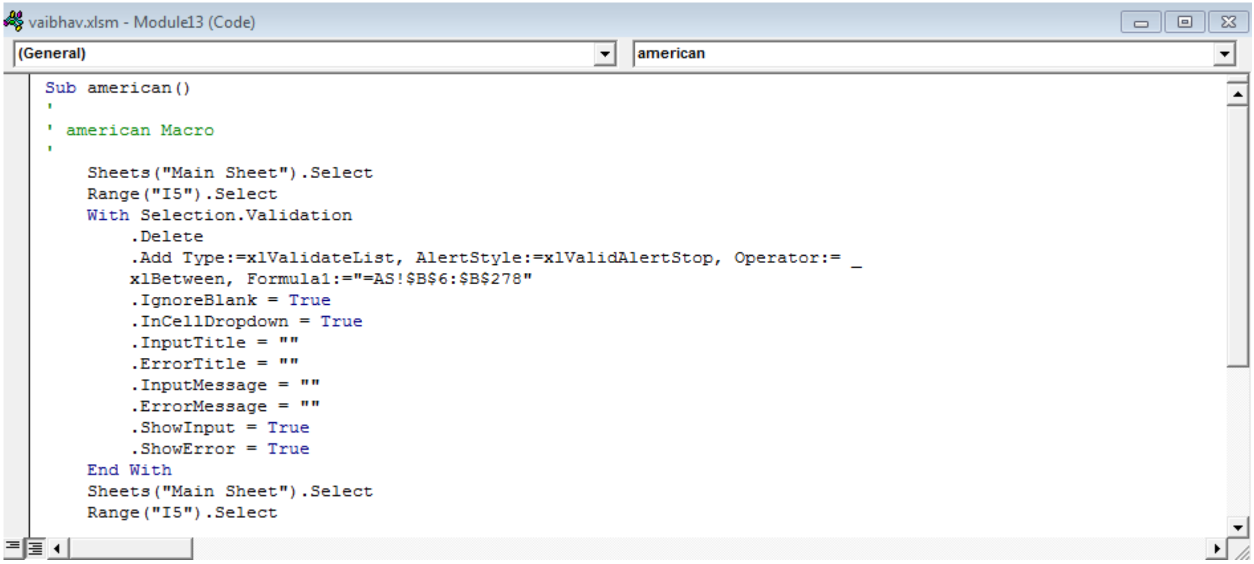


Figure22. Selection of American Code and American Steel Selection from the Main Sheet



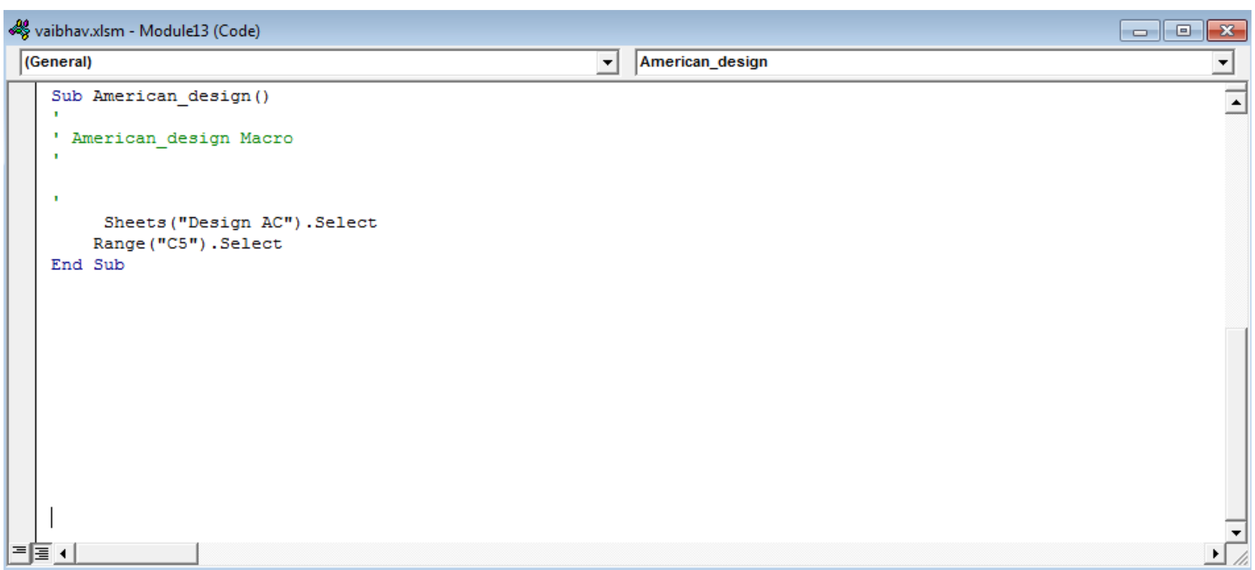
vaibhav.xlsm - Module13 (Code)

(General) | american

```
Sub american()
'
' american Macro
'
    Sheets("Main Sheet").Select
    Range("I5").Select
    With Selection.Validation
        .Delete
        .Add Type:=xlValidateList, AlertStyle:=xlValidAlertStop, Operator:= _
        xlBetween, Formula1:="=AS!$B$6:$B$278"
        .IgnoreBlank = True
        .InCellDropdown = True
        .InputTitle = ""
        .ErrorTitle = ""
        .InputMessage = ""
        .ErrorMessage = ""
        .ShowInput = True
        .ShowError = True
    End With
    Sheets("Main Sheet").Select
    Range("I5").Select
```

Figure23. Visual Basic code for American macro

<u>Step2</u>: Click on the command ‘Design As Per British Code’. Now the macro ‘American_design’ runs and user is taken to a new sheet ‘Design AC’. In this sheet the section is matched from sheet ‘AS’ and properties are displayed.

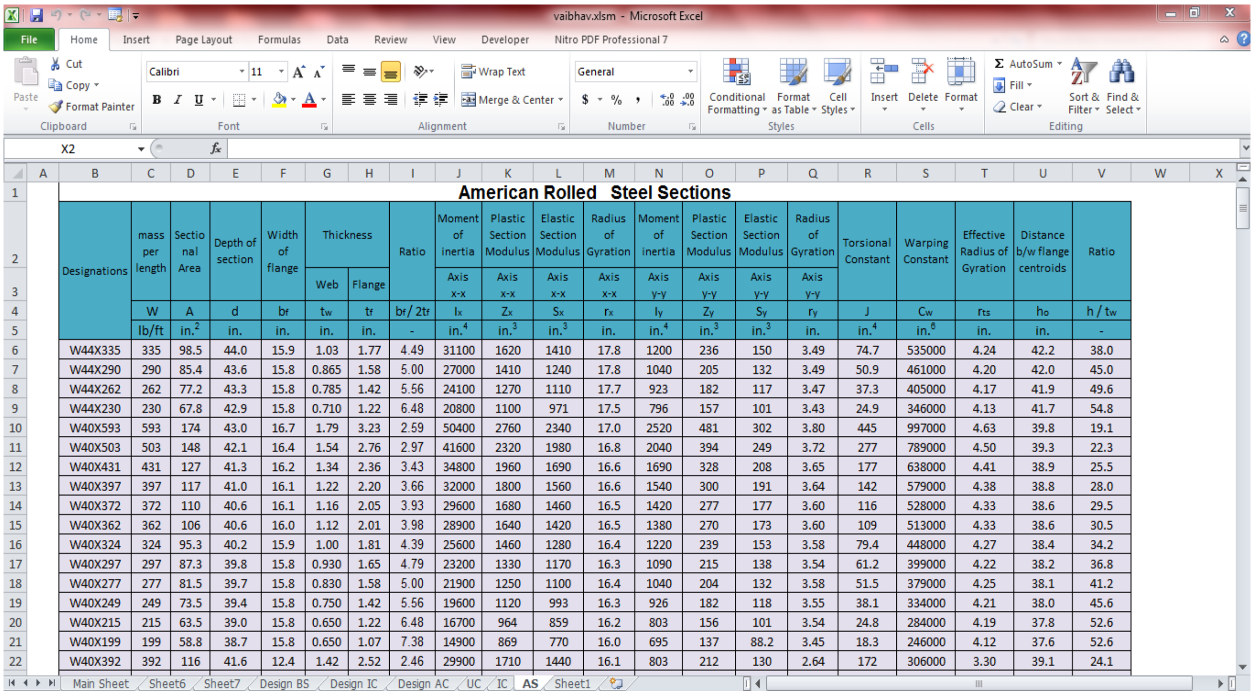


vaibhav.xlsm - Module13 (Code)

(General) | American_design

```
Sub American_design()
'
' American_design Macro
'

'
     Sheets("Design AC").Select
    Range("C5").Select
End Sub
```

Figure24. Visual Basic code for American_design macro

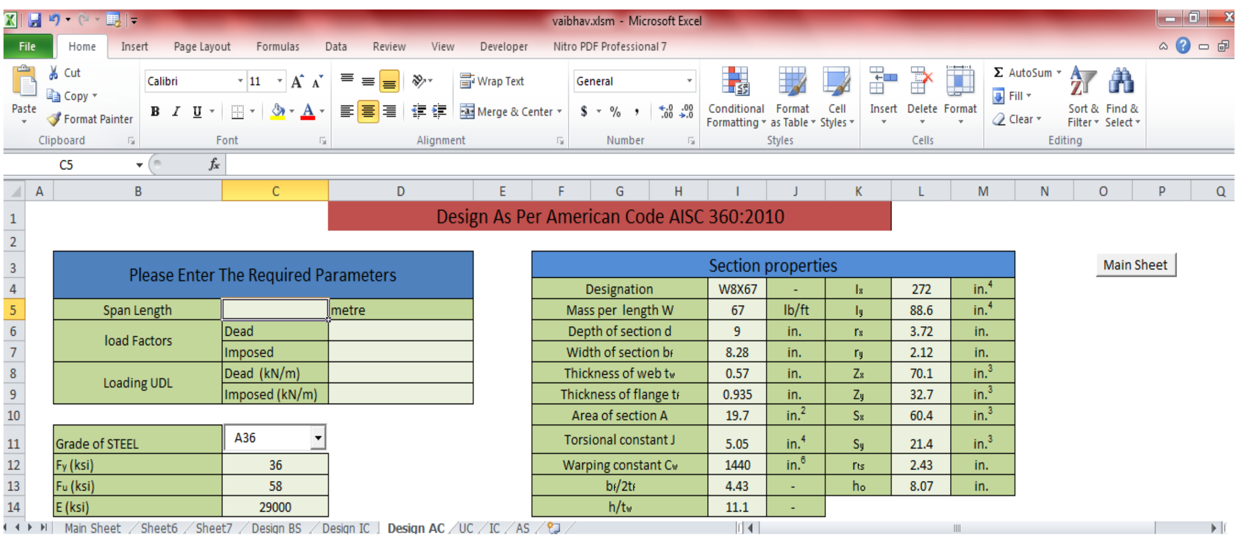


American Rolled Steel Sections

Designations	mass per length	Sectional Area	Depth of section	Width of flange	Thickness: Web	Thickness: Flange	Ratio	Moment of inertia, Axis x-x	Plastic Section Modulus, Axis x-x	Elastic Section Modulus, Axis x-x	Radius of Gyration, Axis x-x	Moment of inertia, Axis y-y	Plastic Section Modulus, Axis y-y	Elastic Section Modulus, Axis y-y	Radius of Gyration, Axis y-y	Torsional Constant	Warping Constant	Effective Radius of Gyration	Distance b/w flange centroids	Ratio
	W	A	d	bf	tw	tf	bf / 2tf	Ix	Zx	Sx	rx	Iy	Zy	Sy	ry	J	Cw	rts	ho	h / tw
	lb/ft	in.^{2}	in.	in.	in.	in.	-	in.^{4}	in.^{3}	in.^{3}	in.	in.^{4}	in.^{3}	in.^{3}	in.	in.^{4}	in.^{6}	in.	in.	-
W44X335	335	98.5	44.0	15.9	1.03	1.77	4.49	31100	1620	1410	17.8	1200	236	150	3.49	74.7	535000	4.24	42.2	38.0
W44X290	290	85.4	43.6	15.8	0.865	1.58	5.00	27000	1410	1240	17.8	1040	205	132	3.49	50.9	461000	4.20	42.0	45.0
W44X262	262	77.2	43.3	15.8	0.785	1.42	5.56	24100	1270	1110	17.7	923	182	117	3.47	37.3	405000	4.17	41.9	49.6
W44X230	230	67.8	42.9	15.8	0.710	1.22	6.48	20800	1100	971	17.5	796	157	101	3.43	24.9	346000	4.13	41.7	54.8
W40X593	593	174	43.0	16.7	1.79	3.23	2.59	50400	2760	2340	17.0	2520	481	302	3.80	445	997000	4.63	39.8	19.1
W40X503	503	148	42.1	16.4	1.54	2.76	2.97	41600	2320	1980	16.8	2040	394	249	3.72	277	789000	4.50	39.3	22.3
W40X431	431	127	41.3	16.2	1.34	2.36	3.43	34800	1960	1690	16.6	1690	328	208	3.65	177	638000	4.41	38.9	25.5
W40X397	397	117	41.0	16.1	1.22	2.20	3.66	32000	1800	1560	16.6	1540	300	191	3.64	142	579000	4.38	38.8	28.0
W40X372	372	110	40.6	16.1	1.16	2.05	3.93	29600	1680	1460	16.5	1420	277	177	3.60	116	528000	4.33	38.6	29.5
W40X362	362	106	40.6	16.0	1.12	2.01	3.98	28900	1640	1420	16.5	1380	270	173	3.60	109	513000	4.33	38.6	30.5
W40X324	324	95.3	40.2	15.9	1.00	1.81	4.39	25600	1460	1280	16.4	1220	239	153	3.58	79.4	448000	4.27	38.4	34.2
W40X297	297	87.3	39.8	15.8	0.930	1.65	4.79	23200	1330	1170	16.3	1090	215	138	3.54	61.2	399000	4.22	38.2	36.8
W40X277	277	81.5	39.7	15.8	0.830	1.58	5.00	21900	1250	1100	16.4	1040	204	132	3.58	51.5	379000	4.25	38.1	41.2
W40X249	249	73.5	39.4	15.8	0.750	1.42	5.56	19600	1120	993	16.3	926	182	118	3.55	38.1	334000	4.21	38.0	45.6
W40X215	215	63.5	39.0	15.8	0.650	1.22	6.48	16700	964	859	16.2	803	156	101	3.54	24.8	284000	4.19	37.8	52.6
W40X199	199	58.8	38.7	15.8	0.650	1.07	7.38	14900	869	770	16.0	695	137	88.2	3.45	18.3	246000	4.12	37.6	52.6
W40X392	392	116	41.6	12.4	1.42	2.52	2.46	29900	1710	1440	16.1	803	212	130	2.64	172	306000	3.30	39.1	24.1

Figure25. Properties of American Steel Sections

Step3: The user is required to fill the parameters along with the grade of steel.



Design As Per American Code AISC 360:2010

Please Enter The Required Parameters		
Span Length		metre
load Factors	Dead	
	Imposed	
Loading UDL	Dead (kN/m)	
	Imposed (kN/m)	

Grade of STEEL	A36
Fy (ksi)	36
Fu (ksi)	58
E (ksi)	29000

Section properties					
Designation	W8X67	-	Ix	272	in.^{4}
Mass per length W	67	lb/ft	Iy	88.6	in.^{4}
Depth of section d	9	in.	rx	3.72	in.
Width of section bf	8.28	in.	ry	2.12	in.
Thickness of web tw	0.57	in.	Zx	70.1	in.^{3}
Thickness of flange tf	0.935	in.	Zy	32.7	in.^{3}
Area of section A	19.7	in.^{2}	Sx	60.4	in.^{3}
Torsional constant J	5.05	in.^{4}	Sy	21.4	in.^{3}
Warping constant Cw	1440	in.^{6}	rts	2.43	in.
bf/2tf	4.43	-	ho	8.07	in.
h/tw	11.1	-			

Figure26. Input parameters to be filled by the user

Step4: After finishing the above work, a detailed result is displayed indicating the status of the section. If the section is unsafe revise the section.

Design As Per American Code AISC 360:2010

Please Enter The Required Parameters		
Span Length	5	metre
load Factors	Dead	1.2
	Imposed	1.6
Loading UDL	Dead (kN/m)	25
	Imposed (kN/m)	18.75

Grade of STEEL	A36
F_y (ksi)	36
F_u (ksi)	58
E (ksi)	29000

Section properties					
Designation	W8X67	-	I_x	272	in.^{4}
Mass per length W	67	lb/ft	I_y	88.6	in.^{4}
Depth of section d	9	in.	r_x	3.72	in.
Width of section b_f	8.28	in.	r_y	2.12	in.
Thickness of web t_w	0.57	in.	Z_x	70.1	in.^{3}
Thickness of flange t_f	0.935	in.	Z_y	32.7	in.^{3}
Area of section A	19.7	in.^{2}	S_x	60.4	in.^{3}
Torsional constant J	5.05	in.^{4}	S_y	21.4	in.^{3}
Warping constant C_w	1440	in.^{6}	r_{ts}	2.43	in.
$b_f/2t_f$	4.43	-	h_o	8.07	in.
h/t_w	11.1	-			

Section Classification	
Web	Compact
flange	Compact
Class of section	Compact

summary of results		
Shear	0.34	PASS
Moment	0.73	PASS
LL defl.	0.78	PASS
DL+LL defl.	1.04	FAIL

Detailed Results: SHEAR CAPACITY	"kip"	"kN"
Actual Shear V_u	33.72	150.00
section shear capacity V_N	99.73	443.59
Usage Factor	0.34 SAFE	

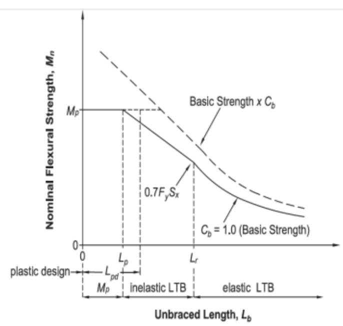


Fig. C-F1.2. Nominal flexural strength as a function of unbraced length and moment gradient.

-

parameters:		
L_p (in.)	105.90	AISC Eq. F2-
L_r (in.)	8.14E+02	AISC Eq. F2-
F_{cr}	43.69	AISC Eq. F2-
M_{cr}	2638.86	

Detailed Results: MOMENT CAPACITY	"kip-in"	"kN-m"
Actual Moment M_u	1659.60	187.53
Allowable Moment M_N	2271.24	256.65
(a) yielding	2271.24	
(b) LTB	2378.67	
(c) Flange Local Buckling	-	
(d) Web Local Buckling	-	
Usage Factor	0.73 SAFE	

Detailed Results: DEFLECTION	
Actual Deflection LL (mm)	10.79
Allowable Deflection LL (mm)	13.89
Usage Factor	0.78 SAFE

Detailed Results: DEFLECTION	
Actual Defl DL+LL (mm)	21.57
Allowable Defl DL+LL (mm)	20.83
Usage Factor	1.04 NOT SAFE

Figure27. Excelsheet showing the adequacy of the beam

3.4.1 VERIFICATION OF DESIGN TOOL WITH STAAD OUTPUT

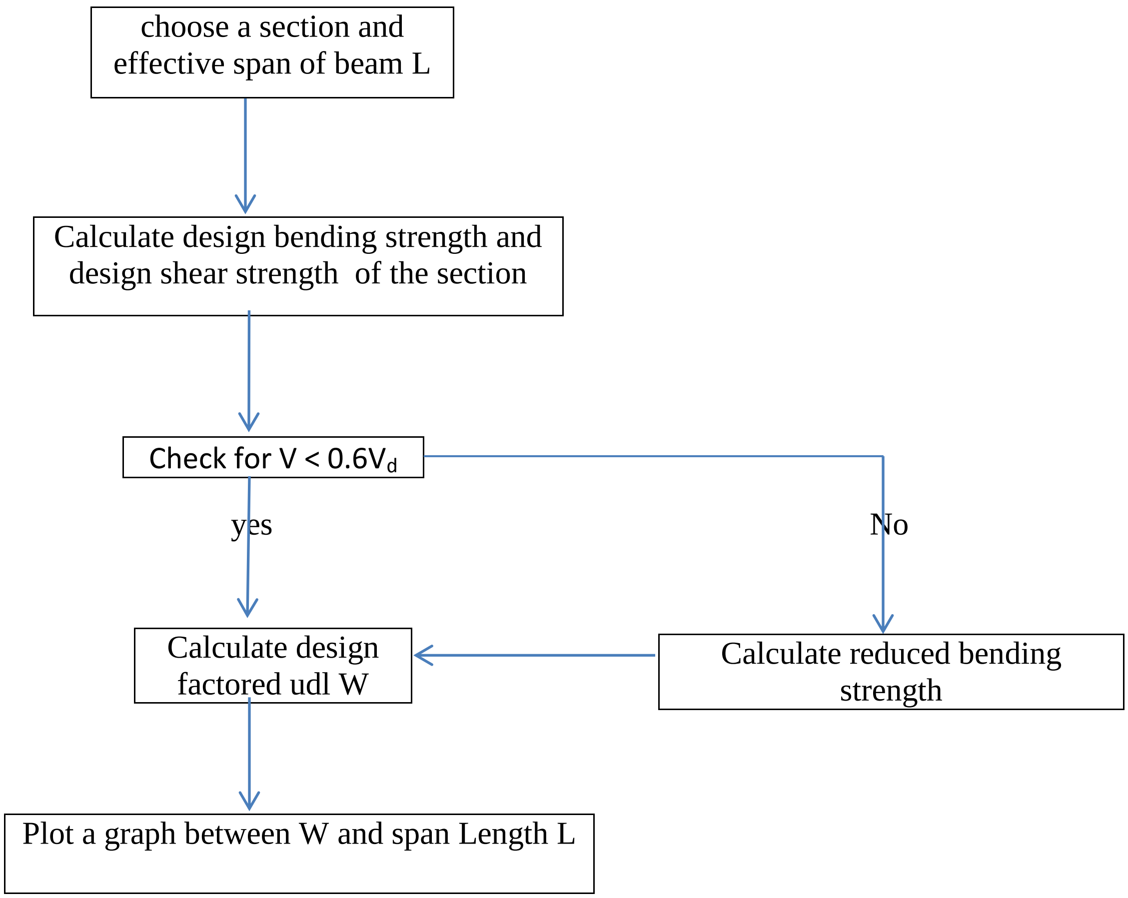
```
                        DESIGN SUMMARY   (KNS-METRE)
                        --------------

     RESULT/      CRITICAL COND/     RATIO/         LOADING/
      FX                MY             MZ            LOCATION
     ===============================================================
       FAIL         DEFLECTION        1.004              1
       0.00 C          0.00           0.00             2.50



|--------------------------------------------------------------------------|
|                                                         Y         PROPERTIES   |
|*************                                            |         IN   CMS UNIT |
|            *   |=============================|     ===|===       ------------  |
|MEMBER    1 *   |  AISC SECTIONS               |        |         AX=0.1271E+3  |
|            *   | ST   W8X67                   |        |    --Z  AY=0.3310E+2  |
|DESIGN CODE *   |                              |        |         AZ=0.6659E+2  |
| LRFD 2001  *   ===============================     ===|===       PY=0.5359E+3  |
|            *                                                     PZ=0.1150E+4  |
|            *   |<---LENGTH (M)=     5.00 --->|                   RY=0.5387E+1  |
|*************                                                     RZ=0.9438E+1  |
|                                                                                |
|                187.5 (KNS-METRE)                                               |
|PARAMETER          |              L1   L1   L1                    CAPACITIES   |
|IN KNS   CMS       |                                              IN KNS METRE |
|---------------    +          L1               L1                 -------------|
| KL/R-Y=   92.82   |                                              PNC=0.1723E+4|
| KL/R-Z=   52.98   +       L1                        L1           pnc=0.0000E+0|
| UNL    = 500.00   |                                              PNT=0.2839E+4|
| CB     =   1.00   +    L1                               L1       pnt=0.0000E+0|
| PHIC   =   0.85   |                                              MNZ=0.2441E+3|
| PHIB   =   0.90   +                                              mnz=0.0000E+0|
| FYLD   =  24.82   |L0                                      L0    MNY=0.1175E+3|
| NSF    =   1.00   +---+---+---+---+---+---+---+---+---+---|      mny=0.0000E+0|
| DFF =    240.00 -10.4                                            VN =0.4436E+3|
| dff =    238.99               ABSOLUTE MZ ENVELOPE               vn =0.1500E+3|
|                                  (WITH LOAD NO.)                              |
```

Figure28. Staad result for beam design using American Code

3.5 DESIGN CHART PREPARATION FOR FLEXURE MEMBERS

The design charts have been prepared using the Indian Standard Code of Practice for laterally supported and laterally unsupported beams. The procedure embraced is represented diagrammatically and then showed with the design examples given underneath.

<u>Design Procedure for laterally supported beam</u>



<u>Design example</u>

<u>Beam Details</u>

Beam span length = 1m

Simply supported beam

Section used = ISLC 150

The section is assumed to be plastic.

Solution:

Properties of ISLC150:

D=150mm

t_w=4.8mm

Z_e=93 X $10^3 mm^3$

Z_p=106.17 X $10^3 mm^3$

Step1: Design capacity of section

d/t_w=24.67 < 67ε

M_d= β_b * Z_p * f_y/Y_{mo}=24.13 kNm <1.2Z_e*f_y/Y_{mo} (=25.36kNm)

V_d=(f_y * h * t_w)/(√3 * Y_{mo})= 94.48kN

Step2: Check for $V \le 0.6V_d$

V=(4* M_d)/L = 96.52 kN

Since V> 0.6 V_d the section fails in shear . And also V> V_d

Hence to calculate the maximum load the section can take for the given length, V is taken equal to V_d .

Step3: Reduced Design capacity of section

β = 1.0

M_{fd} = (Z_p – A_v*y)*f_y / Y_{mo}

= 18 kNm

M_{dv} = 18 kNm

Step4: Calculation of factored uniformly distributed load W

$W = (8^* M_{dv})/L^2$

W = 144 kN/m.

The entire design chart has been prepared in light of the above example demonstrated.

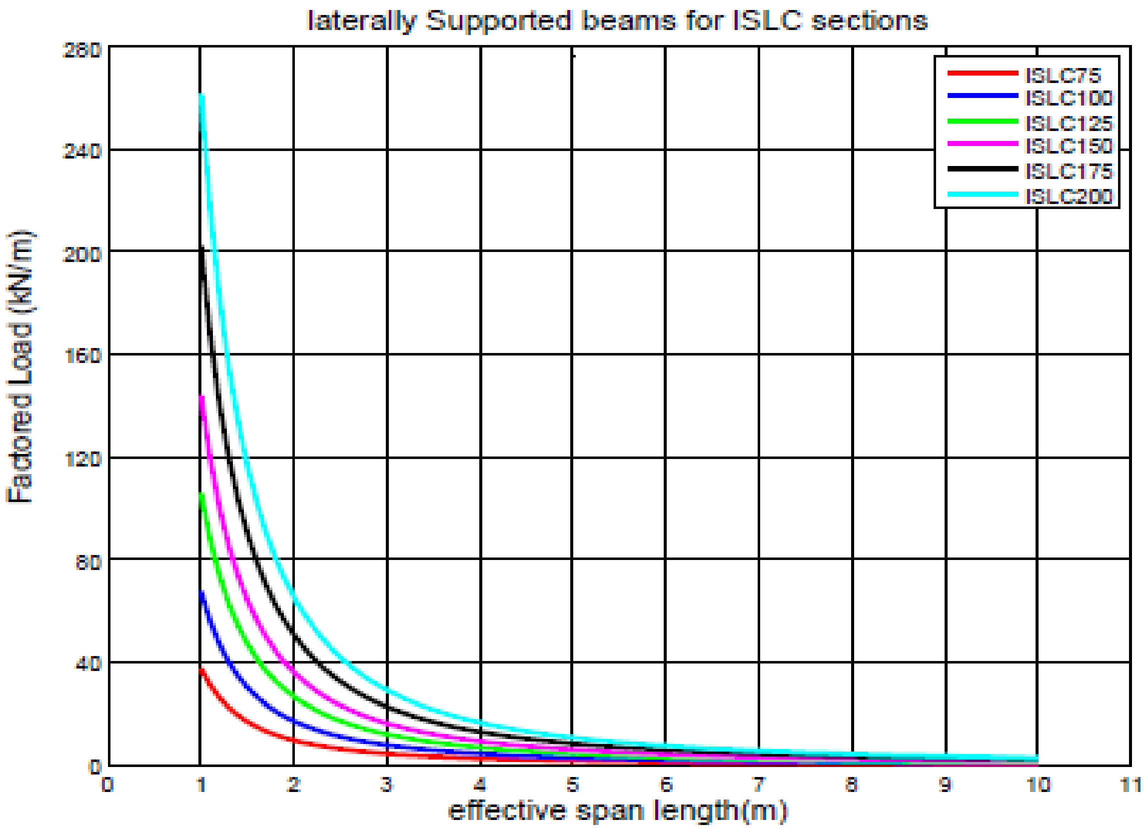


Figure29. Factored load vs effective span length graph for ISLC sections

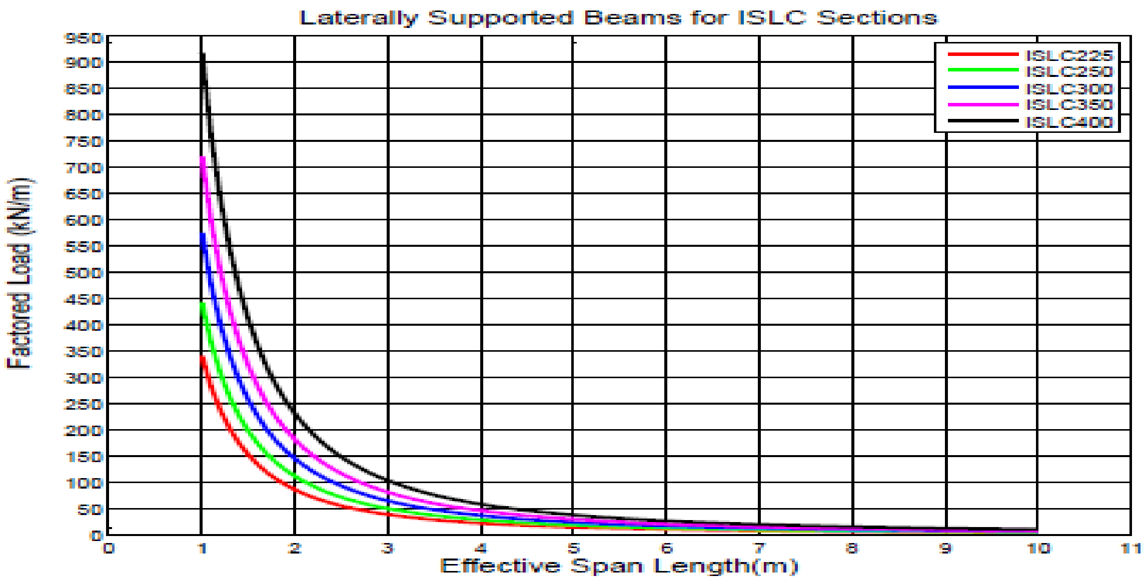


Figure30. factored load vs effective span length graph for ISLC sections

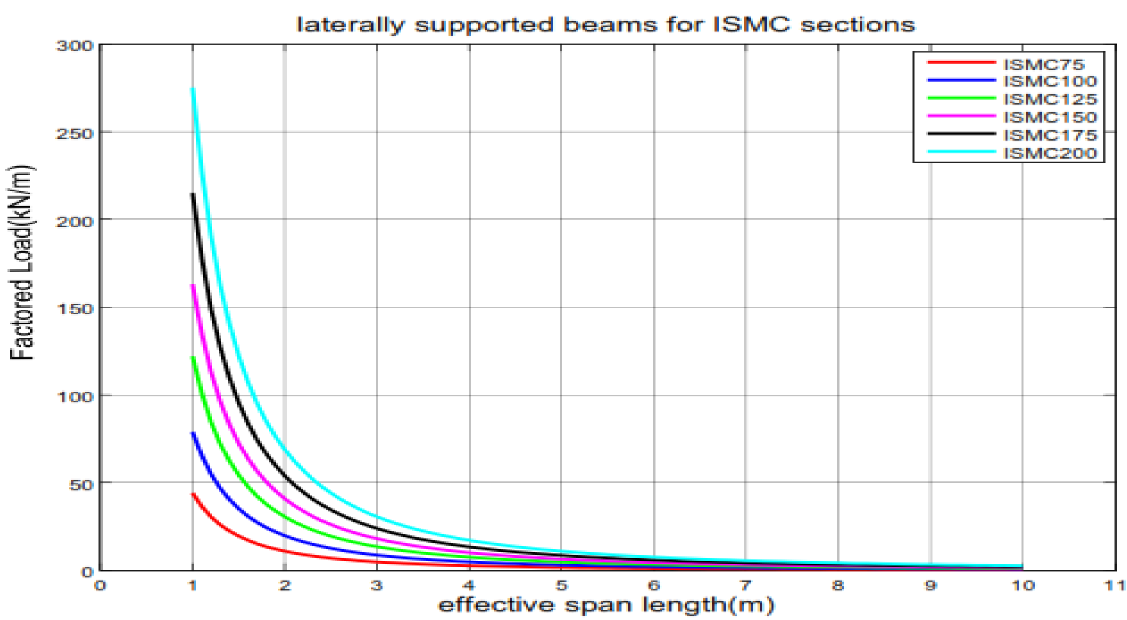


Figure31. factored load vs effective span length graph for ISMC sections

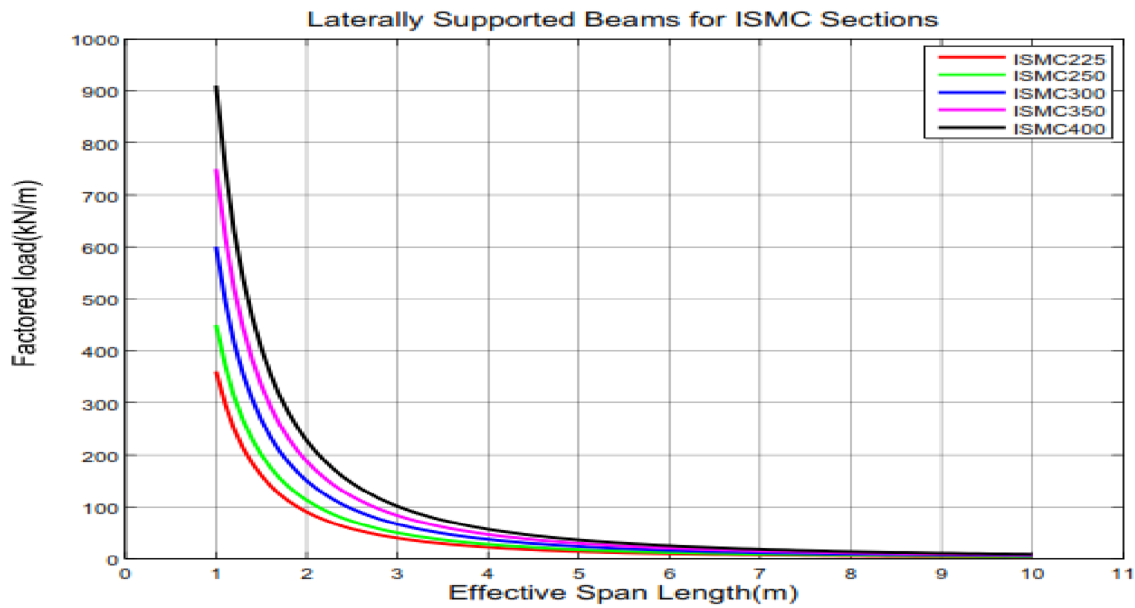


Figure32. factored load vs effective span length graph for ISMC sections

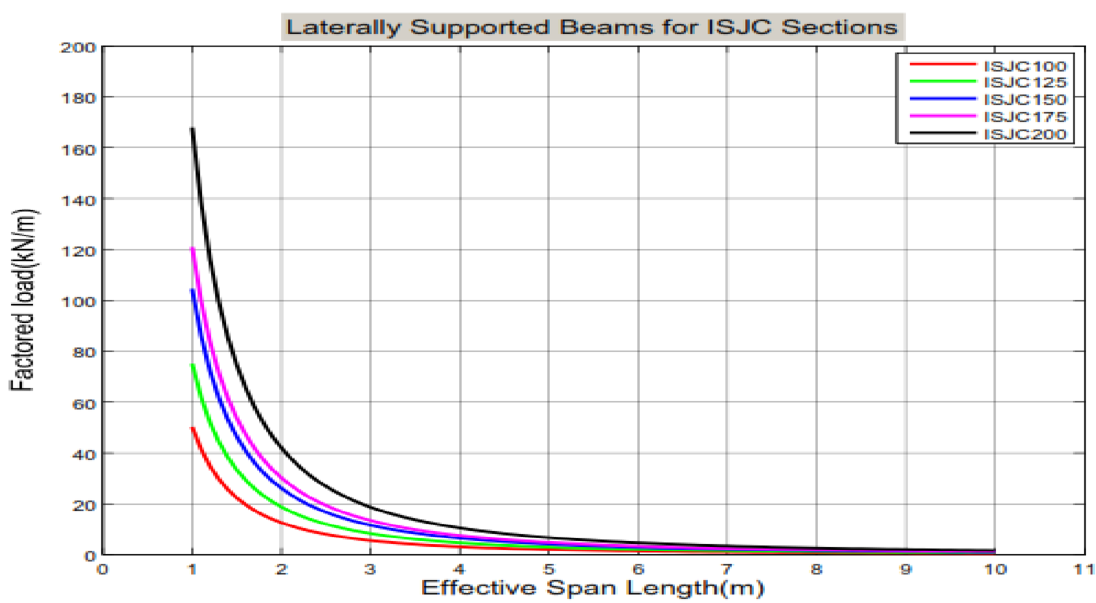
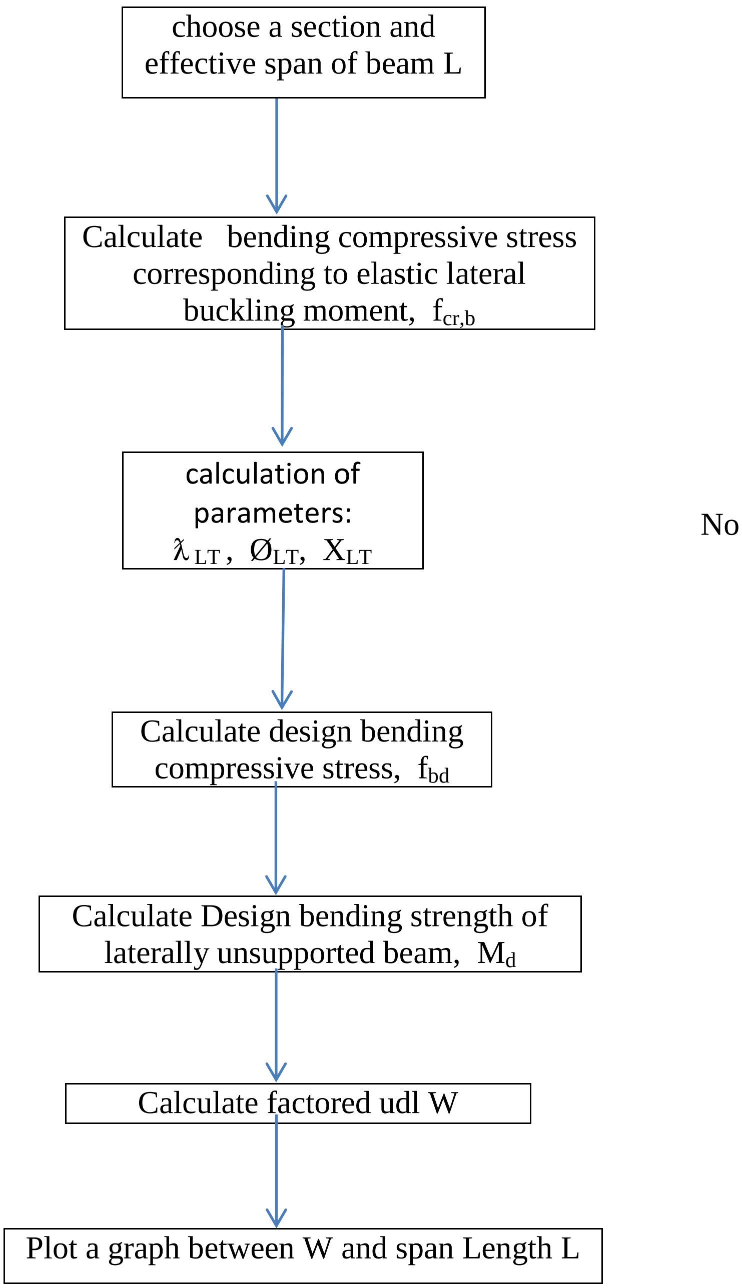


Figure33. factored load vs effective span length graph for ISJC sections

Design Procedure for laterally unsupported beam



Design example

Beam Details

Beam span length = 1m

Section used = ISLC 150

Ends are fully restrained against torsion and warping is not restrained in both flanges.

The section is assumed to be plastic.

Solution:

Properties of ISLC150:

D=150mm

t_f = 7.8mm

t_w=4.8mm

r_y = 23.7 mm

Z_p=106.17 X $10^3 mm^3$

Step1: calculation of bending compressive stress

$$f_{cr,b} = \frac{1.1 * \pi^2 * E}{(L_{LT} / r_y)^2} * \left[1 + \frac{1 * (L_{LT} / r_y)^2}{20 * (h_f / t_f)^2}\right]^{0.5}$$

$f_{cr,b}$ = 1373.25 N/mm^2

Step2: Calculation of parameters

$\bar{\lambda}_{LT} = \sqrt{(f_y / f_{cr,b})}$ =0.43

$\text{Ø}_{LT} = 0.5[1 + \alpha_{LT}(\bar{\lambda}_{LT} – 0.2) + \bar{\lambda}_{LT}^{2}] = 0.62$

$X_{LT} = 1 / [\text{Ø}_{LT} + (\text{Ø}_{LT}^{2} - \bar{\lambda}_{LT}^{2})^{0.5}] = 0.94$

Step3: Calculation of design bending compressive stress

$f_{bd} = X_{LT} f_y / Y_{mo}$

f_{bd} = 213.64 N/mm^2

Step4: Calculation of design bending strength

$M_d = \beta_b Z_p f_{bd} = 22.68$ kNm

Step5: Calculation of factored uniformly distributed load W

$W = (8^* M_{dv})/L^2$

W = 181.44 kN/m

The entire design chart has been prepared in light of the above example demonstrated.

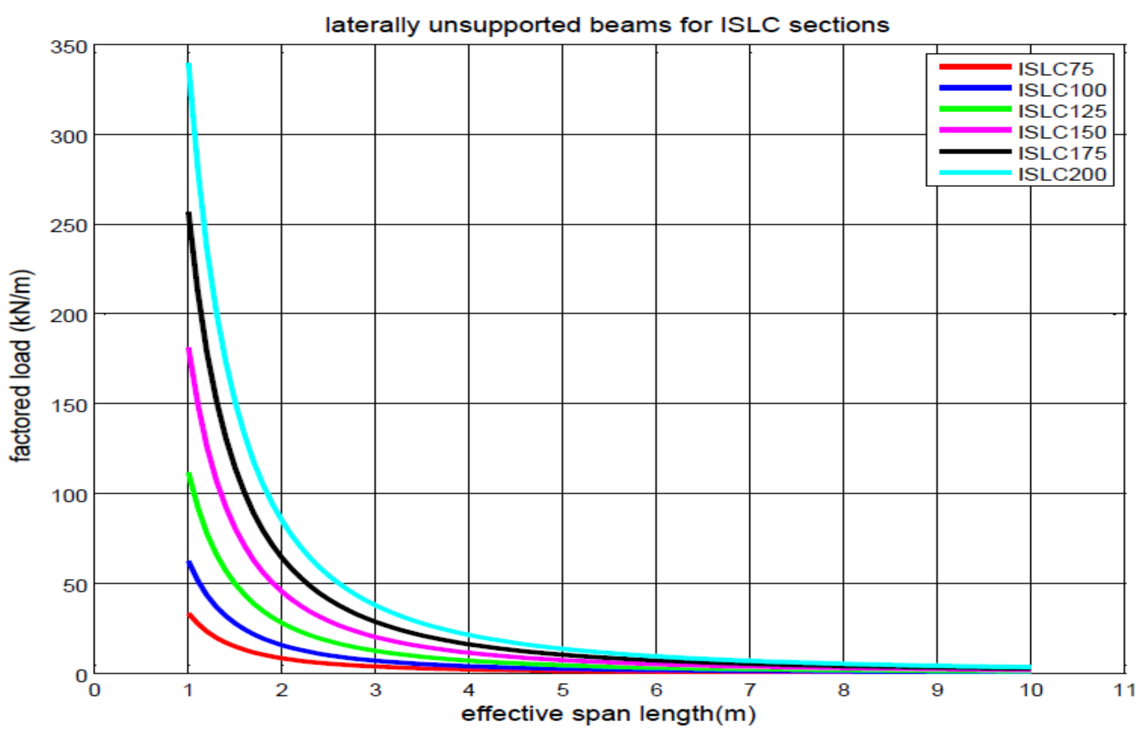


Figure34. factored load vs effective span length graph for ISLC sections

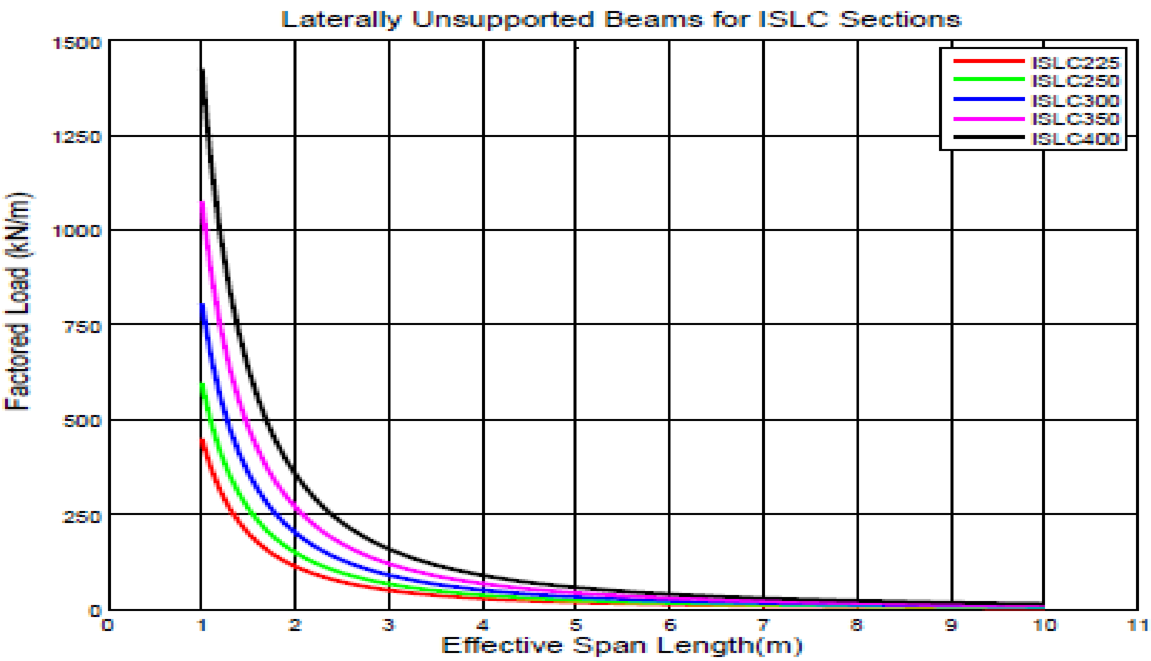


Figure35. factored load vs effective span length graph for ISLC sections

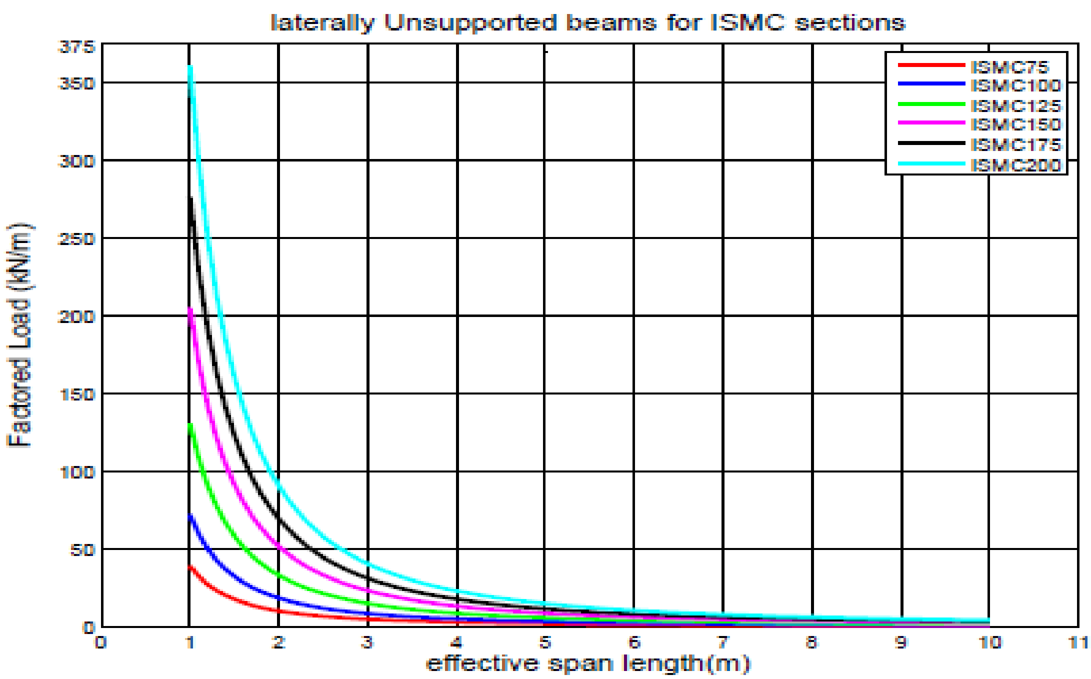


Figure36. factored load vs effective span length graph for ISMC sections

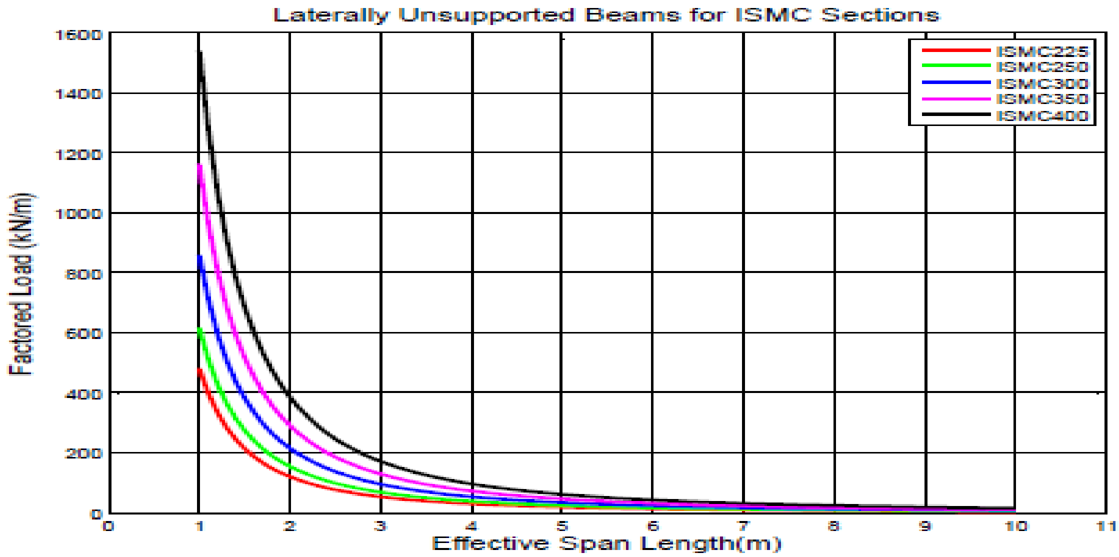


Figure37. factored load vs effective span length graph for ISMC sections

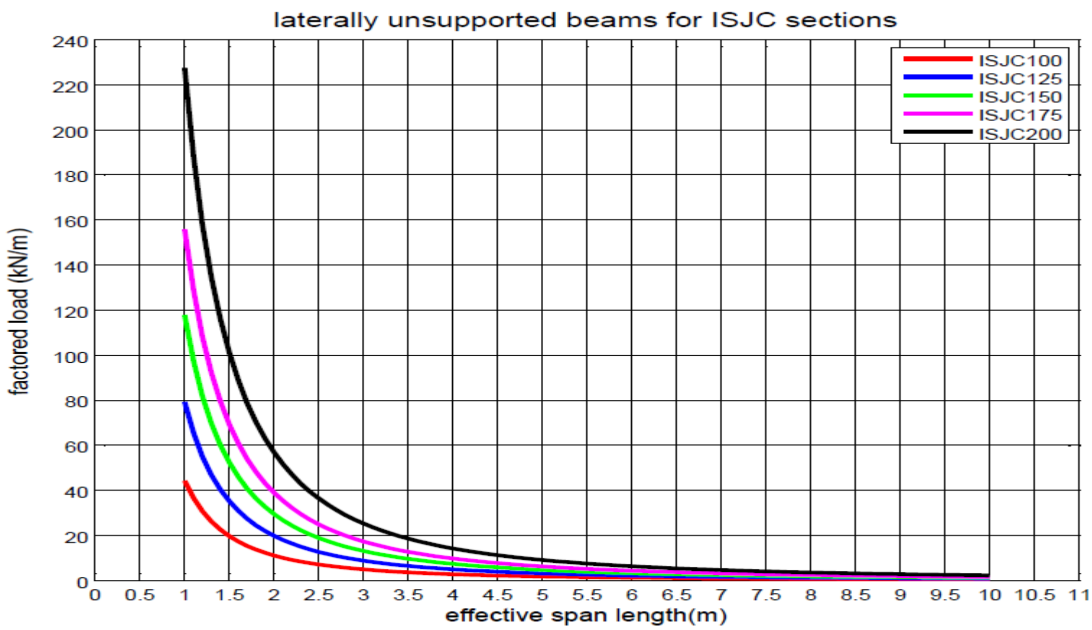


Figure38. factored load vs effective span length graph for ISJC sections

3.6 SUMMARY

From the design methods delineated in the second chapter, the design tools have been developed. The outputs obtained as per various tools are verified also with the help of other software packages or hand calculation using the standards.

CHAPTER 4
CONCLUSION

4.1 CONCLUSION

The objective of this study demands the development of design tools for three prominent standard code groups, Indian Standard, British Standard, and American Standard. Applying the guidelines discussed in second chapter design aids using spreadsheets and charts are developed. Soundly working of these tools are demonstrated by carrying out an example which is being verified with the help of staad output. Charts have been prepared for the purpose of selecting steel sections straightforwardly. The design tools are proven to be much significant and valuable.

4.2 SCOPE OF FUTURE WORK

Spreadsheet development packages offer numerous computational, diagraming, and charting devices that could be used to handle numerous sorts of design aids with sensible exertion. Using them to their fullest improves the nature of design experience. These graphs have been demonstrated profitable. Consequently effort should be made to produce design aids utilizing spreadsheet requisition as a part of all fields of civil engineering.

CHAPTER 5
REFERENCES

REFERENCES

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